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Delivery of a Fiber Optic Cable Repair Course by Videoteletraining

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The feasibility of using videoteletraining (VTT) to deliver a hands-on laboratory course on fiber optic cable repair was evaluated to explore the potential for extending the use of VTT beyond lecture-based courses. Three treatment groups were compared with a total of 50 students: (1) traditional classrooms, (2) VTT local classrooms with an instructor and students, and (3) VTT remote classrooms where students were connected to the local classroom by a two-way audio and video VTT system. There were no significant differences between groups on procedural errors during two connector repair laboratory tasks or on observer ratings of safety and the quality of student work. There were also no significant group differences on a troubleshooting performance test and a written examination. There was a slight trend for remote students to need greater assistance and for their laboratories to take longer. Few differences were found on a student questionnaire. An interaction tally of instructor and student questions showed little differences between groups. The evaluation showed that it was feasible to deliver the course by VTT, given the extra support requirements and marginal travel cost savings for small numbers of students. Findings relevant to delivering other laboratory courses by VTT are discussed and enhanced preparation of remote students prior to performing their laboratory work is suggested as one method to offset the reduced assistance available to remote students.

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Foreword

This report describes research conducted as part of the Navy Personnel Research and Development Center's Distributed Training Technology (DTT) project. The DTT project is part of our Classroom and Afloat Training research program and falls under the Education and Training project (O1772) of the Navy's Manpower, Personnel, and Training Advanced Development Program Element (0603707N). The work was performed under the sponsorship of the Bureau of Naval Personnel. The research evaluated training strategies and technologies to extend videoteletraining (VTT) beyond traditional, lecture-based courses.

The research investigated the feasibility of using videoteletraining to deliver a course in fiber optic cable repair. The findings have direct implications for the design of future distance education systems in the Navy and elsewhere.

The recommendations in this report are intended for use by the Commander, Naval Sea Systems Command, the Chief of Naval Education and Training, and the Chief of Naval Personnel in developing policy for the application of VTT in the Navy.

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Summary

Problem and Background

Many Navy personnel requiring training are geographically separated from training resources. Videoteletraining (VTT) enables an instructor to teach multiple classes at different geographic locations. VTT has been an efficient and cost beneficial way to deliver training and is in operational use by the Chief of Naval Education and Training (CNET) within the CNET Electronic Schoolhouse Network (CESN). VTT has been used for lecture-based instruction and additional cost savings could be achieved if other types of content could be delivered by VTT, such as student laboratories. A fiber optic cable repair course was selected as a representative hands-on laboratory course because it contained a range of challenging activities that included instructor demonstrations and student laboratories for several types of fiber optic connectors, the use of test equipment, and a hands-on performance test.

Objective

The objective of this research was to experimentally evaluate the feasibility of using videoteletraining to deliver a training course with hands-on laboratories. The variety of hands-on laboratories contained in the Fiber Optic Cable Repair course provided a test bed for developing methods to extend the utility of VTT beyond lecture-based courses.

Approach

Three treatment groups with a total of 50 students were compared: (1) traditional classrooms, (2) VTT local classrooms with an instructor and students, and (3) VTT remote classrooms where students were connected to the local classroom by a two-way audio and video VTT system. Four VTT classes were convened with a total of 16 local and 16 remote students, and two traditional classes were convened with a total of 18 students. The groups were compared in terms of procedural errors and observer ratings made during connector repair laboratories, a troubleshooting performance test on faulted fiber optic systems, help received by students during laboratories, final examination scores, student questionnaire responses, and an observer tally of interaction over the network.

Results and Conclusions

There were no significant differences in student performance indicating impairment for remote site students as a consequence of delivering the course by VTT. Procedural errors during two connector repair laboratories were no higher for remote students than they were for either local or traditional students. Errors declined about 20% from the first to the second laboratory, suggesting that student performance improved with experience. There were no significant group differences on observer ratings of safety, the quality of student work, or objective light loss readings for the connectors. Safety ratings were lowest for wearing eye glasses and controlling fiber fragments, but these were found in a minority of all students (6-7%). There was a slight trend for greater instances of help for remote-site students and for them to aid one another more than the other groups. A video microscope used to show connector ends over the VTT system was found beneficial in allowing

remote site student work to be inspected by the instructor and for other students to observe examples of acceptable and unacceptable work.

Troubleshooting test performance on faulted fiber optic systems also revealed no significant differences between the treatment groups in finding a fault, or in identifying possible fault causes and corrective actions. Students required less help and less time to solve the fault on the second of two test systems and this improvement was slightly less pronounced for remote students. Help given to students during the performance test predominately concerned troubleshooting logic, followed by test equipment. The fiber optic systems were installed on roll-away carts, illustrating the adaptation of equipment to be portable so it can be moved in and out of VTT classrooms that are used for other courses as well.

Remote-site students generally required more time to complete laboratory periods than did the other groups. A tally of interactions across the network indicated little disadvantage for remote-site students in the level of instructor-student interaction during lecture and demonstration sessions when all students participated as a combined class. During laboratories where students worked individually or in small groups, the network was used primarily by remote students to ask questions of the instructor. Scores on a multiple-choice final examination did not differ significantly between groups. Student questionnaire responses revealed few significant differences between the treatment groups. The groups did not differ in their perceptions that some course activities were more difficult to perform than others. Most VTT students indicated that they would take another VTT course and they were more accepting of VTT as a method of instruction than were traditional students who had not experienced VTT.

It is instructionally feasible to deliver the Fiber Optic course by VTT based on the results of the experiment. Enhanced preparation of students prior to performing their laboratory work was identified as a method to offset the reduced assistance available to students who are at a distance from the instructor. Examples of this preparation in this study included the use of videotapes, computer-based instruction, and moving topics taught during laboratories into lectures and demonstrations given prior to conducting laboratories. Delivery of this course by VTT would increase demands on VTT site personnel and would involve additional room preparation and support logistics. A VTT facilitator would need to be present during student laboratories as a safety monitor and to assist students and the instructor. Offering this course by VTT would offer marginal savings in travel costs because of the small number of students per class, although other laboratory courses with greater throughput could provide cost savings.

Recommendations

The following recommendations are for the Commander, Naval Sea Systems Command, the Chief of Naval Education and Training, and the CNET Electronic Schoolhouse Network.

1. Experimental delivery of the Fiber Optic Cable Repair course by videoteletraining indicated that this method of delivery is feasible and could be attempted as a regular VTT offering.

2.The decision to offer this and other laboratory courses by VTT should weigh liabilities which include obtaining additional equipment for sites, the extra course support requirements on VTT site personnel, and the marginal cost savings when there are small numbers of students.

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Introduction

Problem

Many Navy personnel who must receive training are geographically separated from training resources. An increasingly efficient approach to meeting this requirement is needed as the Navy downsizes and training resources become constrained. Videoteletraining (VTT) has been found to be an efficient and cost beneficial way to address this issue because it enables a single instructor to teach multiple classes that are at geographically remote locations. The Chief of Naval Education and Training (CNET) now has VTT in operational use in the CNET Electronic Schoolhouse Network (CESN). This VTT system utilizes an interactive two-way video and audio television system that allows distant *remote site* students to participate in the instruction originating from a *local site* where other students are co-located with the instructor.

VTT has generally been used for the delivery of lecture-based instruction. Even with current VTT technology, there is some reduction in the quality of the audio and video as compared with live instruction; e.g., it reduces the visibility of personnel at different classroom locations and also reduces the ability of instructors and students to interact as they do in a traditional classroom. These constraints make it more difficult to conduct training that is not instructor centered, such as a variety of courses with student laboratories and learning environments that are highly interactive. Travel or instructor costs could be avoided if such training could be delivered via VTT rather than in traditional classrooms. However, the use of VTT for courses with student laboratories containing hands-on activities may require somewhat different conversion and delivery techniques than those used for typical lecture-based courses.

A training course on fiber optic cable repair[1] was selected as being representative of hands-on laboratory courses with activities that present difficulties for using the VTT medium. The course was selected as a result of interest by the Naval Sea Systems Command (NAVSEA) in the feasibility of using VTT to deliver this and other hands-on courses.[2] It is a relatively new course offering that covers fiber optic technology used on recently constructed ships. The demand for learning this technology is expected to increase the number of future course convenings. This course contains several types of hands-on activities that include instructor demonstrations and student laboratories for fiber optic connectors, the use of test equipment, and a troubleshooting performance test.

Objective

The objective of this research was to experimentally evaluate the feasibility of using videoteletraining to deliver a training course with hands-on laboratories. The variety of hands-on laboratories contained in the Fiber Optic Cable Repair course provided a test bed for developing methods to extend the utility of VTT beyond lecture-based courses.

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[1]This course is commonly referred to as the Fiber Optic Cable Repair course and that term will be used for convenience here, although the formal designation for the course is the "Interim Fiber Optic Organizational Maintenance Course" (J-670-1200).

[2]Letter 1500, Ser 04MP/5163 of 6 January 1992; Subject: "NAVSEA participation in current training research and development." Washington, DC: Commander, Naval Sea Systems Command.

Background

Previous research and development has demonstrated that VTT can be an efficient and cost-beneficial method to deliver training electronically to remote Navy personnel (Bailey, Sheppe, Hodak, Kruger, & Smith, 1989; Rupinski & Stoloff, 1990; Rupinski, 1991; Simpson, Pugh, & Parchman, 1990, 1991a, 1991b, 1992, 1993; Stoloff, 1991; Wetzel, Radtke, & Stern, 1993, 1994; Wetzel, 1995). This research on the use of VTT in Navy training has shown that typical lecture-based courses can be delivered by VTT without detrimental effects on achievement. Prior research on instructional television also indicates that student achievement is not affected by this method of delivery and that any initial unfavorable attitudes lessen as a result of experience with the medium (Wetzel, et al., 1993, 1994). The major cost benefits of video teletraining systems are in circumstances where travel and per diem costs are avoided by usage that is intense enough to offset the costs of the technology. Courses that are particularly beneficial in reducing travel costs are those with a high student throughput and which are short in duration (a week or less). Historical cost data developed by the CESN from 1989 through 1995 indicate that the system reaches the break-even point approximately half way through a year (i.e., VTT system costs are approximately half the travel and training costs that are estimated to have been avoided).

The possibility of using VTT for a wider range of courses would extend the cost and efficiency benefits of VTT beyond the lecture-based courses that are typically delivered by VTT. A substantial amount of Navy technical training involves laboratories and hands-on activities.[3] However, the interactive nature of hands-on laboratories present more of a challenge when conducted live over a VTT system. Previous research with Navy courses containing other than lecture-based content includes the hands-on laboratories in a Damage Control Petty Officer course (Simpson, et al, 1992), computations and plotting performed in Celestial Navigation student laboratories (Wetzel, 1995), and the interactive processes involved in Navy leadership training (Simpson, Wetzel, & Pugh, 1995; Wetzel, Simpson, & Seymour, 1995). In-progress work to be reported later includes hands-on computer laboratories in a Quality Assurance course. Other research has suggested that a fully interactive two-way audio and video VTT system is primarily of benefit as a monitoring convenience for the instructor (Simpson, et al., 1991b, 1993). However, the use of this two-way audio-video configuration would be mandatory for laboratory courses so that the instructor can view student work and monitor their progress over the system.

Another realm of research on the instructional uses of film and video has shown these media can be used for demonstrations of a variety of procedural and skill-based training (Wetzel et al., 1993, 1994). Trainees typically watch these demonstrations prior to performing the tasks themselves. These demonstrations serve as a standard for students to judge their performance, serve to reduce variability in instructor behavior and therefore standardize the instruction, and can be used conveniently for repeated viewings. Compared with still images, demonstrations shown in motion provide critical discriminations, convey continuity information, facilitate learning a motion itself, and directly present information difficult to describe verbally. However, this research also indicates the value of having actually performed the task compared with merely watching the

[3]Surveys conducted in the mid 1980s showed that training administrators identified some form of laboratory in as many as three fourths of their courses. Training objectives involving procedural learning were also found to be the most frequent objective beyond those involving basic factual information (Wetzel, Van Kekerix, & Wulfeck, 1987a, 1987b).

demonstration. Videoteletraining research conducted by Simpson, et. al. (1992) compared these conditions in the hands-on laboratories of a Navy damage control course. Students allowed a hands-on laboratory experience performed somewhat better on two tasks compared with students seeing a videotaped demonstration prior to performing the tasks, but those watching the videotape performed better on another task for nonassembly steps that apparently were better conveyed in the videotape.

Approach

The approach to delivering the fiber optic course was dictated by concerns with the physical absence of the instructor for remote students and the ability to see remote students and instructor demonstrations shown over the system. The absence of the instructor raised the possibility that remote students could be disadvantaged in receiving assistance and this might affect student performance, procedural errors, and safety practices. Three instructor demonstrations of connector repair tasks involved detailed views of a variety of small tools, materials, and fine motor skill procedures. Another instructor demonstration involved operating two pieces of test equipment and interpreting the meaning of various displayed readings. Five student laboratories required remote students to perform tasks on their own and to use the VTT system to consult the instructor for assistance that would have normally been provided when the instructor circulated among students during the laboratory. Three of these laboratories immediately followed the respective demonstration of the connector work. A demonstration and lecture preceded a laboratory where students practice using test equipment in preparation for subsequent troubleshooting performance test.

The approach to delivering the fiber optic course consisted of several elements that were based on two complementary themes: using technology to assist in delivering the course and enhancing instruction in portions of the course to better prepare students for working in laboratories. The elements exemplifying this approach to the course were: (1) video taped demonstrations of connector tasks were used to ensure that remote students did not miss details that could be observed during live demonstrations, (2) roll-away portable equipment was used to allow the temporary installation of equipment in classrooms that are used by other courses, (3) computer-based instruction was used to prepare students for a laboratory on troubleshooting, (4) certain lecture topics were enhanced to prepare remote students for performing laboratory work, and (5) additional camera views were used to enhance demonstrations and to enable a remote presence. These included a microscopic camera to allow remote inspection of student fiber optic connectors, and a microphone-based video switching system that allowed individual remote site students to be viewed when they asked questions. These elements of the approach constituted a candidate set of modifications logically required to deliver an adequate VTT course. The contribution of these elements was not separately evaluated and they were not used in delivering two traditional classes studied for comparison purposes. The research simulated the local and remote classroom conditions because this was a study of feasibility rather than an evaluation of an implemented VTT course.

Method

The methods for conducting the evaluation study are described below in terms of the instructional events of the course, the treatment groups, outcome measures, and the methods used to convert the course. The outcomes of interest were a comparison of student performance in several laboratories, student assistance required in laboratories, the level of interaction in VTT courses, student evaluations on a post-course questionnaire, and student written examination performance.

Description of Course

Students enrolling in the course were from Navy technical ratings where fiber optic cable systems are used for a variety of shipboard equipment. Two Electronic Technician (ET) First Class Petty Officers taught different portions of the course. Students are provided with a trainee guide covering facts and concepts discussed during lectures, procedural steps for connector repair laboratories, operation of test equipment, and assignment sheets with questions to be answered as homework (COMTRALANT, 1993). Connector repair procedures described in the trainee guide were the basis for the scripts of three videotapes and the error checklist to be described later. The instructional events for the five days of the course are as follows:

1. Monday: View three connector repair videotapes in VTT but not traditional classes, all-day instructor lecture on theory portion of class, and computer-based instruction is made available for VTT classes only.

2. Tuesday: Instructor demonstration of installing ST connector followed by student laboratory. Instructor demonstration of installing rotary splice connector followed by student laboratory.

3. Wednesday: Instructor demonstration of Hughes connector and backshell followed by student laboratory, and instructor lesson on test equipment and troubleshooting followed by student laboratory using actual fiber optic systems mounted in portable carts.

4. Thursday: Instructor led homework review and student performance test on troubleshooting faulty systems.

5. Friday: A question and answer review period precedes the administration of a written test followed by a review of answers on the test, student evaluation questionnaires are completed, and student certificates are issued as the class ends.

Connector Laboratories

ST Connector Laboratory. The ST connector encases a glass fiber in the center of a tubular ceramic ferrule that is attached to a bayonet connector (see Figure 1). Each student in this laboratory installed a pair of ST connectors on the ends of one cable. The steps for establishing the fiber in the connector fall in four broad phases. The specific steps within these phases were derived from the trainee guide and were also the basis for the script of the videotape (see Appendix A for detailed procedural steps listed in the observer check list).

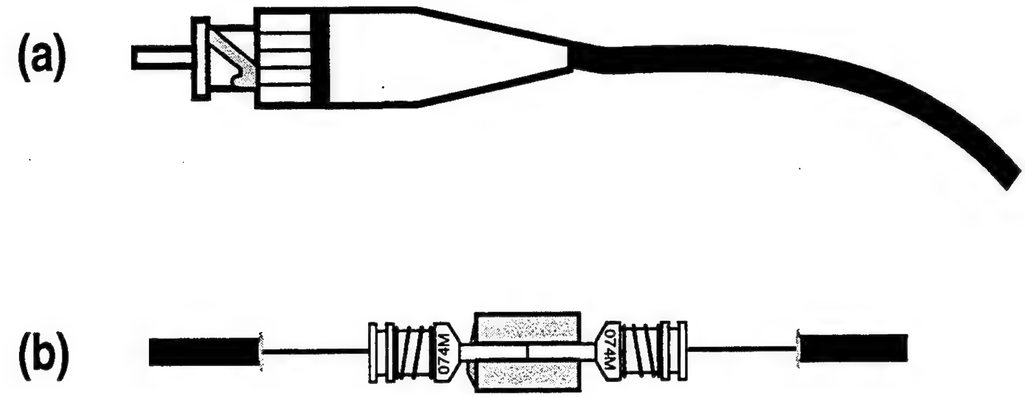

Figure 1. Fiber optic connectors: (a) ST connector, (b) rotary splice connector.

Phase A consists of preparing the fiber cable by removing the plastic jacketing and exposing the glass fiber with a special buffer removal tool. Phase B consists of epoxy preparation, injecting epoxy into the ferrule channel, inserting the fiber, installing and crimping a cable sleeve to affix the cable to the connector, and then curing the epoxy in an oven. Phase C consists of using a cleaving tool to score the fiber, detaching the exposed fiber, and disposing of the fiber fragment on masking tape. The cleaving task involves a visual factor in being able to see a small fiber and a tactile skill of not applying too much lateral force. The fiber can be broken with the tool or when the fiber is removed, which can result in a shatter that goes down inside the ferrule. Phase D consists of polishing the connector and any small amount of glass fiber that protrudes with two grades of polishing paper, and then cleaning, visually inspecting, and testing the completed product. Excessive force applied during the initial contact with the polishing paper can also shatter the fiber down into the connector. The pair of ST connectors installed on one cable by a student are tested with an Optical Loss Test Set (OLTS) for an acceptable light loss reading of -0.5 decibels (db) or less.

Rotary Splice Connector Laboratory. The rotary mechanical splice connector was used to repair a break introduced in the middle of a fiber optic cable. Two matching clear glass ferrules are mated to one another with a mechanical spring clip that aligns the ferrules so the fibers meet end-to-end (see Figure 1). Four broad phases cluster the steps in this procedure in a manner similar to that with the ST connector (Appendix B gives the specific steps of the rotary splice procedure). A number of the procedural steps are similar to those used with the ST connector. During this laboratory, the student cuts the cable on which the ST connectors were previously installed and then inserts a rotary splice connector.

Phase A consists of preparing the cable by removing the plastic jacketing and then exposing the glass fiber with the buffer removal tool. Phase B involves preparation of an ultraviolet (UV) adhesive, injecting the adhesive into the ferrule channel, inserting the fiber, and curing the adhesive under a special UV lamp. Phase C consists of cleaving or scoring the fiber, detaching the exposed fiber, and disposing of the fiber fragment on masking tape. Phase D consists of polishing the fiber and ferrule with two grades of polishing paper, cleaning and visually inspecting the ferrule, joining

the two ferrules in a spring-clip assembly with a matching gel, and testing the product. Polishing frequently takes much longer than with the ST connector because the UV adhesive is much harder than the epoxy used for the ST connector. It is possible to break the plastic ferrules with too much lateral force when using a polishing puck that is used to hold the ferrule. The ferrules are often rotated within the clip to achieve the lowest light loss reading on the OLTS. An OLTS reading of -1.0 db or less was judged acceptable in the student laboratory (i.e., -0.5 db for the two ST connectors on the same cable and -0.5 db for the two rotary connectors).

Hughes Connector and Hughes/Veam Backshell Laboratory. The Hughes connector incorporates multiple fiber optic cables having termini ferrules that are aligned within the connector. Two versions of the connector use different backshells that differ in the amount of space for cables housed behind the connector (Hughes backshell and Veam backshell).

The full procedure given in Appendix C for the Hughes connector and backshell consists of assembling portions of the connector, stripping the fibers, cleaving the fibers, preparing epoxy and inserting the fibers within termini, polishing the fiber and termini, inserting the termini into the connector, and assembling the remainder of the connector. The full procedure was not performed in student laboratories because of the unavailability of sufficient connectors and materials. Two to four students worked in teams to familiarize themselves with the parts of an existing connector and then performed assembly and disassembly of the connector.

Test Equipment and Troubleshooting Laboratories

Test Equipment Laboratory. The instructor lectures and then demonstrates the operation and use of two pieces of fiber optic test equipment prior to a student laboratory: an Optical Loss Test Set (OLTS) and an Optical Time Domain Reflectometer (OTDR). The lecture includes material on the techniques of troubleshooting fiber optic cable systems. A subsequent student laboratory is performed by student teams that typically consisted of two students. The students practice using the equipment on three fiber optic systems that are not faulted and function normally. Students may occasionally test one another by introducing a fault into a system. The laboratory continues for about 75 minutes until the students feel confident in their understanding of the functioning of the systems and equipment use.

Troubleshooting Performance Test. Students were required to successfully solve two problems on two different fiber optic systems installed in portable carts, each of which contained a single faulted fiber optic system. If a student was unsuccessful, the student was required to continue with a third or fourth system until two problems had been completed successfully. Students were given one hour for each test and were cautioned to avoid compromising the test by talking to other students. During VTT classes, there were two system carts in the local classroom and two carts in the remote classroom. All four carts were in the same room during traditional courses. The four carts were rotated among the local and remote classrooms so that the faults used for testing were given equally often to these two treatment groups. Typical test problems involved either a damaged or occluded connector end, or a missing sleeve that caused the connectors to be misaligned.

Students used the OLTS and OTDR during the test and were provided with documents diagraming the system and documenting the unfaulted system readings. Students filled out a work sheet form with the following steps. The students first took a total system light-loss measurement with the OLTS, and then used the OTDR to obtain a view of the connector points along the path of the faulted system. The OTDR measures small light reflections from the connector points in the path of the system and displays these on a small CRT screen. Based on this information, students listed the possible causes for the fault shown by the test equipment readings. Students then used the test equipment to further locate the fault and recorded on the form the injection/detection points used and any db loss readings. Once a fault had been located, students recorded the fault on the form and listed possible corrective actions to correct the fault. The corrective actions generally fell in two categories, an immediate solution such as an alternative path, and an ultimate solution, which would involve a repair action. Students then entered a single corrective action to be taken to correct the fault in the near term. Depending on the fault, students could correct the fault under the direction of the instructor and then make a post-corrective system loss measurement with the OLTS.

Students were required to obtain the initials of the instructor or facilitator on the test form at selected points during the test. Students also consulted with the instructor during the test to clarify issues concerning the fault in the test system. In traditional classes, these exchanges were typically discussed in a subdued voice so that pertinent test information would not be compromised if overheard by other students who were to troubleshoot that system fault at a later time. These private consultations were a problem during early VTT classes. The public nature of the VTT system allowed all students to hear conversations and this inhibited the ability of remote students to consult with the instructor while attempting to avoid compromising the test. During subsequent classes, a procedure was adopted where remote students used the telephone to hold private conversations with the instructor. A long telephone cord was used so students could continue to work at their system cart when seeking the instructor's counsel on interpreting a system fault.

Experimental Design

The treatment groups, subjects, evaluation measures, and the methods for converting the course are described below.

Treatment Groups

A single independent variable (type of instruction) with three states was used. This variable consisted of three treatment groups: (1) a traditional laboratory classroom where students were with an instructor, (2) a VTT local classroom where students were also with an instructor, and (3) a VTT remote classroom where students were connected to the local classroom by a fully interactive two-way audio and two-way video VTT system. The VTT local and remote conditions were simulated in the sense that students were located in different VTT classrooms within the same building. During VTT classes, a second instructor acted as a VTT facilitator in order to serve as a safety monitor for the VTT remote students.

There were several differences between the VTT classes and the traditional classes: (1) VTT classes saw three connector repair videotapes on the first morning, whereas traditional classes saw

no videotapes. (2) VTT classes inspected connector ends with a video microscope in addition to using optical viewers from the repair kits, whereas traditional classes only used the optical viewers. (3) VTT students watched video monitors to see instructor demonstrations that were performed on the base of a document camera or shown by other cameras described later, whereas the traditional students clustered around a table to watch the instructor. (4) VTT classes were provided with computer-based instruction (CBI) on trouble shooting that was not given to the traditional classes. As a consequence of these differences, the two VTT groups were the most comparable because they received exactly the same instructional presentations and both groups shared the same course modifications that were not present for traditional students.

Students

A total of 50 students participated in the study. Students were in classes convened by the Advanced Electronics School (AES) located at the Fleet Training Center (FTC) in San Diego. There were 16 VTT local students, 16 VTT remote students, and 18 traditional classroom students. Thirty-nine of the 50 students were in the Electronics Technician (ET) rating, and the remaining 11 were in other ratings (1 Fire Control, 1 Electronic Warfare, 3 Data Systems, and 6 Interior Communications technicians). The rank of the students varied from E-2 to E-7, with the average military rank for the three groups being 5.2 for local, 4.9 for remote, and 5.1 for traditional classes. Although the VTT remote students were slightly more junior, this difference was not significant by an analysis of variance, $F(2,47) = 0.27, p > 0.05$. Student questionnaire ratings on prior experience with fiber optics were also not significantly different between groups (as reported later, the local group gave slightly higher ratings for prior knowledge of concepts and facts in fiber optics).

The students in the study were drawn from six class convenings that followed an initial dry-run convening of the course. The dry-run course allowed instructors to practice teaching to five AES instructors who served as students, and allowed researchers to tryout and refine the experimental measures. The sequence of dry-run and experimental class convenings used in the research was as follows:

June 27, 1994	Traditional "dry run" class (5 instructors as students)
July 18, 1994	VTT class (4 local, 4 remote students)
August 29, 1994	VTT class (4 local, 4 remote students)
October 17, 1994	Traditional class at AES (9 students)
October 24, 1994	VTT class (4 local, 4 remote students)
November 14, 1994	VTT class (4 local, 4 remote students)
January 9, 1995	Traditional class at AES (9 students).

Evaluation Measures

The evaluation outcome measures (dependent variables) are described below and are summarized in Table 1.

Table 1

Data Collection Summary

ST, Rotary Splice, and Hughes connector laboratories:
Procedural Errors
Help and assistance to students
Observer safety and work product ratings
Light loss readings
Performance test:
Performance in locating fault and answers on system test form
Time to complete test
Help and assistance to students
Interaction tally during lectures, demonstrations, and laboratories
Student grades on multiple choice examination
Student questionnaire

Connector Laboratory Measures. Four measures were recorded during student connector laboratories. Three of these measures were recorded on the pages of one combined connector laboratory observer form: observer records of task procedural errors, observer safety and work product ratings, and help sought by or given to students. The fourth measure was a VTT interaction tally that was recorded during the entire course and is described later.

There were three versions of the connector laboratory observer form, one for each of the ST, rotary splice, and Hughes connector tasks. Each connector task form listed the procedural steps over several pages (Appendices A, B, and C list the procedural steps). The form contained boxes next to each step for indicating an error, an omitted step, instances of help or assistance, and observer comments. A code was entered to indicate whether instances of help and assistance were initiated by the student, instructor, or facilitator. Observer comments were written to explain the circumstances of an error or assistance needed. At the conclusion of the student laboratory, observers completed the final page of the rating form that contained safety and work product rating items pertaining to the entire laboratory.

Each observer made recordings on the connector laboratory observer form for two students at a time. Four observers were present during each class convening. All four observers were present in the traditional classroom and two each were present in the local and remote classrooms. A balancing scheme was employed to ensure that observers were rotated between local and remote classrooms equally often over the four VTT class convenings.

1. *Task Procedural Errors*. The steps for each of the connector procedures used for the observer form were derived from the course trainee guide (COMTRALANT, 1993). The steps of the procedure on the form were supplemented by substeps that listed any relevant safety or technique

information given in the trainee guide. This list of steps was also the basis for the three videotapes developed for the experimental version of the Fiber Optic course.

Observers wrote comments to explain errors committed and the help received by a student. These comments were useful in tracking errors or problems that spanned several steps (e.g., an earlier error caused a problem at a later point). It was possible for multiple errors to be scored at a given step in the procedure, such as an error for each end of a connector, a failure to wear safety glasses at various points in the procedure, or a failure to clean a connector during a repetition of a step during polishing.

2. *Student Help and Assistance*. The assistance sought by or given to students was assessed during student laboratories to determine if these forms of interaction would be impaired for remote students. Observers recorded the help and assistance given to students during laboratories in terms of whether it was initiated by a student, the instructor, or the facilitator. There were five categories of help, which were recorded using the following notation:

Student to Instructor	S-->I
Student to Facilitator	S-->F
Student to Student	S-->S
Instructor to Student	I-->S
Facilitator to Student	F-->S.

The first three categories involved help and assistance that was initiated by a student from either the instructor, facilitator, or another student, respectively. The last two categories involved either instructor initiated or facilitator initiated help and assistance that was directed toward the student. These exchanges directed toward the student included offering help to the student and interventions or corrections that were deemed necessary by the instructor or facilitator. The two categories applying to the facilitator were only recorded for remote-site students because there was no facilitator with the VTT local and traditional students. There were several instances where remote students approached the facilitator and the facilitator in turn redirected the question to the instructor. These instances were generally scored as S-->I, and future uses of this help measure should probably include an additional category for this circumstance (e.g., S-->F-->I)

3. *Safety and Work Product Ratings*. At the end of the laboratory the observers completed the final page of the connector rating form. This page contained six items for rating the student on safety, eight items for rating the student's work product, and two spaces for recording the actual db loss values from the OLTS obtained for the student's connector (the rating items and scales used are listed in Appendix D).

The eight safety items were phrased in terms of correct behavior (e.g., wore safety glasses when required). These items were rated on a three point scale that assigned the following values so that a higher number reflected correct behavior: (1) rarely, (2) mostly, (3) almost always.

The work product checklist was also scored on a three point scale that assigned the highest value (3) to an acceptable aspect of the work product, an intermediate value (2) to a marginal product, and the lowest value (1) to a poor product. Items 1-3 referred to whether a fiber was broken during cleaving, by mishandling, or showed a shatter visually. These items were scored 1 if these

events occurred twice, 2 if once, and 3 if not at all. Items 4-8 involved rating if there was connector damage, if the polish quality appeared poor visually, if a bad product required repeat steps, if cleaning practices were poor, and if there was an excessive amount of light loss. These items were scored 3 if there was no problem, 2 if marginal, and 1 if there was a definite problem.

The judgement of an excessive amount of light loss in Item 8 was assigned the highest score (3) if both connector ends were acceptable, the marginal score (2) was assigned if one connector end was bad and the other was acceptable, and the lowest score (1) was given if both connector ends were unacceptable. For the ST connector, an acceptable OLTS reading was -0.5 db or less (both directions were scored). For the rotary splice connector, an acceptable OLTS reading was -1.0 db (i.e., -0.5 db for the rotary plus -0.5 db for the previously installed ST connectors). When unacceptable ST connectors were known to have been present from the previous laboratory, the arithmetic difference between the ST readings and the rotary readings was often used to judge the quality of the students rotary work (i.e., -0.5 db for the rotary connector after subtracting the prior ST readings).

Troubleshooting Performance Test Measures. Students were given a 1 hour time limit to solve the problem and to complete a work sheet form to document their findings. During the test, an observer recorded the start and end times for each student, help and assistance received by the student, and ensured that the student's final paper work had been completed so it could be used for analysis.

Student help and assistance was recorded in a manner similar to that described for the connector laboratories. However, the Student-to-Student category was not included for the performance test because students were not allowed to talk to one another during the test. VTT local and traditional students had no facilitator, so this category of help did not exist as it did for VTT remote students. These codes were additionally subdivided into three categories reflecting the type of interaction that was observed during the dry-run class. These were: (1) form help, such as when a student did not understand what entries should be made on the system record form, (2) test equipment help pertaining to the use of the OTDR and OLTS, and (3) troubleshooting logic help, such as when a student had obtained relevant data but did not understand how to interpret it and arrive at a solution.

VTT Interaction Tally. An observer recorded the frequency of interaction among sites during the first 4 days of the VTT classes. The interaction tally was recorded for interactions that occurred over the VTT network and involved recording the frequency of events in several categories given below. Interactions had to be related to course content. Start and end times for each class period were recorded on the tally form in order to account for variations of these periods over different class convenings. A check mark was entered in a box corresponding to whether an interaction was associated with the local site or the remote site for each interaction category. The principal categories of interaction were whether a question was initiated by the instructor or by a student. The tally subdivided instructor questions (that were answered) according to whether the instructor left the question open for any site to answer, named a specific site that should answer the question, or named a specific student to answer. Student questions were subdivided into those that were initiated by the student and those that extended into longer back-and-forth conversations and exchanges. Unanswered questions and reminders to local students to use their microphone were also recorded. These categories are fully defined in Appendix E. In a previous study, rater

agreement was found to be generally high for these tally categories when two raters observed the same class periods (Wetzel, 1995).

Student Questionnaire. A 56 item questionnaire was developed to assess student evaluations of the course (see Appendix F). The questions were organized in terms of the following general categories: (1) background and prior experience with the course material, (2) instructors, (3) learning and classroom activities, (4) training aids, (5) interaction/participation, (6) overall course rating, (7) adequacy of portions of the course, (8) video-teletraining, and (9) open-ended questions soliciting comments on VTT, likes and dislikes about the course, and suggestions for improvements. Most of the questions (45 items) used a rating format where agreement or disagreement with a statement was rated on a five point scale ordered as follows: (1) Strongly Disagree, (2) Disagree, (3) Neither Agree/Disagree, (4) Agree, (5) Strongly Agree. The remaining questions consisted of four multiple-choice items, a five-point rating item on the pace of the course, two fill-in-the-blank items, and four open-ended questions, one of which was a second part of a multiple-choice item.

There were two versions of the questionnaire, the full version given to VTT local and remote students (56 items), and an abbreviated version given to traditional students (44 items). Twelve items in the full questionnaire were omitted from the version given to traditional classes because the items related to VTT topics and could not be answered by traditional classes (Items 20-23, 37, 42-47, and 49-50). Item 48 was prefaced by a short paragraph describing VTT so traditional students could answer what method of instruction they would prefer for the course.

Final Written Examination. The final written examination on the last day of the course consisted of 34 multiple choice items covering information from the trainee guide. An alternative form of the test was available for retesting students who did not pass the initial version of the test. Students passed the examination by correctly answering 75% or more of the items.

VTT Course Conversion and Apparatus[4]

The course conversion methods followed the general methodology developed for the Navy by Simpson (1993). The adaptation of the course to VTT required a concerted analysis and planning phase to address potential difficulties associated with each course segment. The apparatus and technologies described below were developed as a result of this analysis, instructors learned and practiced behaviors appropriate to VTT, and various remote-site student support mechanisms were developed.

The adaptation of the course for delivery by VTT included the following elements: (1) videotaped demonstrations of connector repair procedures, (2) computer-based instruction on troubleshooting, (3) a video microscope to show connector ends, (4) two portable cameras used during demonstrations and laboratories, (5) an automated system of cameras provided a view of remote-site student workstations, (6) course equipment was adapted to be portable, and (7) progressive revisions were made to the way laboratory instruction was conducted. These elements of the approach were not evaluated separately because the rationale was to provide a candidate set

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[4]There is no implied endorsement for any of the commercial products mentioned in this report. In most cases there are alternative products that could have been employed and mention of these products simply documents the actual equipment used in this study. Product names and brands mentioned herein are trademarks of their respective holders.

of changes representing those required to deliver an adequate VTT course. Local and remote students shared these course conversion elements and traditional students did not, although all students benefited from progressive enhancements to lectures given prior to equipment and troubleshooting work that occurred during the study.

Instructional Adaptations. When the instructor was distant from students during laboratories, normal interactive exchanges and one-on-one adaptive forms of instruction were more difficult to accomplish because the instructor could not circulate among the remote-site students. It became apparent during early classes that some topics were normally conveyed to students in this fashion during the test equipment and troubleshooting laboratories. These topics were moved into enhanced lectures and demonstrations given prior to the laboratory. Thus, material was given before the laboratory in order to better prepare remote-site students to perform their work more independently in the absence of an instructor within the room.

Lecture Slides and Graphics. Instructional slides and graphics presented during the Monday lecture were presented by 35mm slides shown via a Navitar brand 35mm slide projector, which converted the image to a video image for broadcast on the VTT system. An initial VTT class used 8.5 x 11" color overhead transparencies, which were presented on the backlit document camera stand. The use of these transparencies was discontinued in later VTT classes in favor of the 35mm slides because the latter provided a better quality image.

Connector Repair Videotapes. Three videotaped demonstrations of the connector repair tasks were prepared, each approximately 25 minutes in duration. The rationale for using the tapes was to ensure that remote students received the best possible views of the demonstration in the event that performing the demonstration live would not reliably show detailed views and critical aspects of the task. The videotapes covered three topics: ST connector, rotary splice connector, and the Hughes connector and Veam backshell. The edited tapes were narrated and contained scenes of a Navy Fiber Optic course instructor at the Norfolk, VA Fleet Training Center. The content of the tapes was based on the trainee guide and the material typically used by the instructor during live demonstrations. The script for the videotapes closely paralleled the procedural steps listed in Appendices A, B, and C. The tapes duplicated most of material used in the live demonstrations by the San Diego instructors during VTT classes.

The videotapes were shown during the first class session prior to the lecture for VTT classes and were not shown in traditional classes. A TV/VCR tape player was made available in both local and remote classrooms for students who wanted to review the tapes. None of the students who initially saw the tapes used them for review, but several students who were not present during the initial viewing reviewed the tapes at a later time.

Computer-based Instruction. The computer-based instruction (CBI) consisted of eight problems, with each representing a different fault in a fiber optic cable system. The CBI allowed the student to use standard fiber optic troubleshooting procedures to solve each fault. The CBI was designed around (1) a simulated Optical Loss Test Set (OLTS) that provided light loss readings through the fiber system, and (2) a simulated Optical Time Domain Reflectometer (OTDR) that presented a view of junctions in the system and allowed the student to localize the area of a fault. At each step in the troubleshooting sequence the student was required to follow the proper procedure, evaluate test results, and answer questions relating to the troubleshooting step before

proceeding to the next step. The CBI gave the student feedback on his or her performance at each troubleshooting step and at the end of each fault problem. The CBI was developed with Asymetrix Toolbook software and ran under the Microsoft Windows operating system. The CBI was provided on two computers in the local classroom and another two computers in the remote classroom. The computers were located together at the side of each room.

Video Microscope. Figure 2 shows the video microscope that was constructed for this course. The device allowed connector ends to be viewed over the VTT system. Each of the local and remote rooms was equipped with the device. A high resolution video camera (400 lines) was used with a reversed 6-12mm (4x-7x) zoom lens that allowed 110x to 190x magnification. This range of magnification allowed approximately 65% to 90% of the 2.5 mm diameter ST or rotary connector to be shown, depending on the zoom lens position and the under/over scan of the video monitor used. This magnification was as good or better than some of the optical fiber viewers used in the course. The camera and lens were mounted on a photographic X-Y positioner to allow both forward-backward and left-right movement relative to the connector being shown. The connector being shown was inserted into a hole drilled in a round piece of plastic, which was held in a optical lens holder with a vertical rack and pinion adjustment. The X-Y positioner holding the camera and the lens holder were mounted on a small optical table. The fiber optic connector was illuminated by a small gooseneck reading lamp. With the exception of the camera and lens, this device was constructed from off-the-shelf optical table parts from the Edmund Scientific Company catalog.

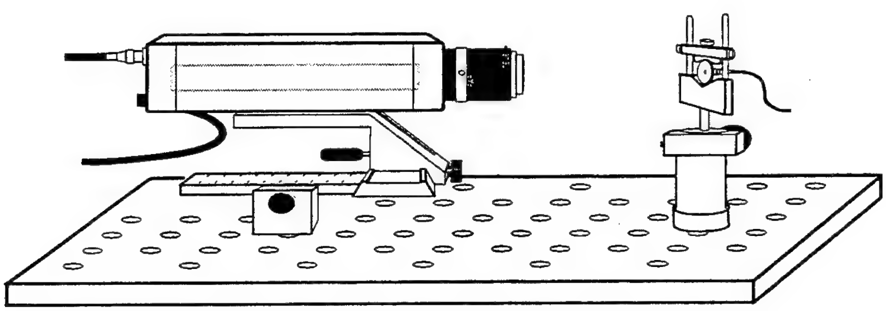

Figure 2. Video microscope used to view connector ends.

Roll-away Carts. Prior to the adaptation of the course to VTT, the fiber optic systems that students used during laboratories were installed on the walls of the traditional classroom with fiber optic cable running between the junction boxes. Because VTT classrooms must be reused for a variety of courses, the fiber systems had to be configured so that they were portable and could be moved in and out of the VTT classrooms. Standard 19" electronic equipment racks (40" high) were adapted to accommodate the fiber optic systems as shown in Figure 3. A vertical panel was attached on top of the cart in order to mount fiber optic cable junction boxes to each side of the panel. The cable system was coiled inside the cart and was accessed through connectors mounted in a wall of the cart or through the junction boxes. There were four carts, with two in each of the local and remote classrooms. During performance tests, the carts were placed on opposite sides or ends of the room to maximize the distance between the carts. This separation reduced the likelihood that conversations would be overheard that could compromise the solution to a test problem.

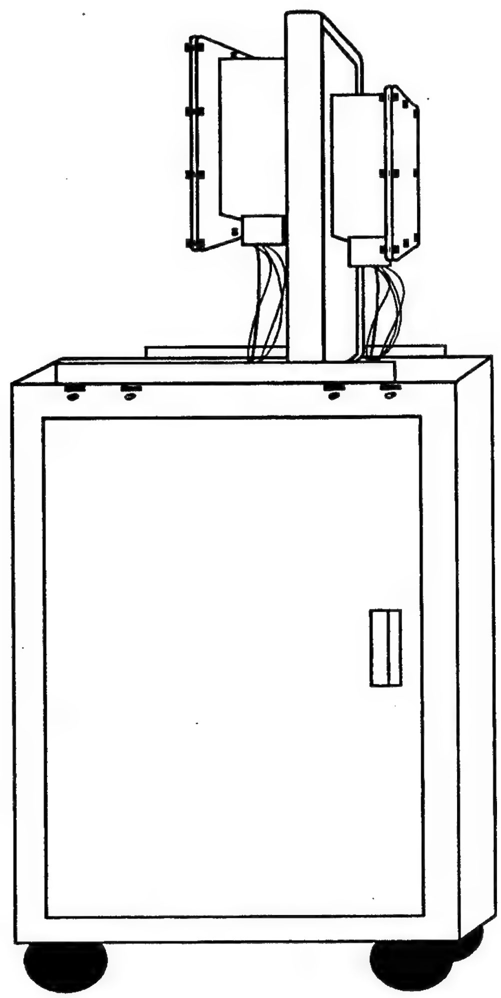

Figure 3. Portable roll-away fiber optic system cart.

Classroom and Instructor Podium Video Equipment. The VTT classrooms were equipped with a fully interactive two-way video and two-way audio digital VTT system. Digital video was transmitted at 384 Kbps using a VTEL brand 386 MediaMax Codec and Multipoint Control Unit. Students viewed all instruction on two large TV monitors located in the front corners of the classroom (45" diagonal monitors in the local room and 60" monitors in the remote room). Two 25" monitors at the back wall of each room showed a view of the outgoing video and the incoming video from the other site. Students in the two rooms could hear each other when they used push-to-talk microphone located on each student table. Students were instructed in the use of the VTT system on the first day of class. Students in the local classroom were reminded to use the push-to-talk microphones so that remote sites could hear them.

The outgoing video from a classroom was selected with a hand-held remote control that allowed switching among several camera sources: a view of the instructor from a camera on the rear wall of the room, a view of students from a camera mounted on the front wall of the room, a videocassette recorder (VCR), and one of several video sources located at the instructor podium.

A manual six-input video switch attached to the instructor podium allowed one of several devices to be selected as the outgoing video from that location. The primary device used at this location during typical lecture-based courses is an Elmo brand video presenter (document camera on an easel copy stand). This device is used to show hard copy materials. The VTT classrooms were not equipped with chalkboards or whiteboards. The other video devices switched from the podium were a Video Labs brand "FlexCam," a small table top Canon VC-C1 brand video camera, a video-based 35mm slide projector, and the video microscope.

The Video Labs brand "FlexCam" is a small camera mounted on a flexible gooseneck rod that allows the camera to be easily positioned in a variety of directions. This camera was used to show an array of small parts laying outside the range of the document camera during instructor demonstrations (e.g., the UV curing lamp or connector oven). The FlexCam was connected to a long cable so that it could be taken to other tables within the room, such as to a student workstation in order to show student work or test equipment being used by a student.

The Canon brand VC-C1 camera uses a hand-held remote that allows up to six preset pan/tilt/ zoom setting to be stored in memory. These preset views are activated by pressing six buttons associated with each view. This camera was used during instructor demonstrations of the OTDR to switch among views of the OTDR screen, the control knobs and buttons, and an overall view of the entire front panel of the OTDR. In remote classrooms, it could also be used to show views of student OTDRs.

Microphone Switching System at Remote Site. A switching system was developed which allowed each of four student workstations at the remote site to be viewed when a student pressed his or her push-to-talk microphone. Four cameras were mounted on poles attached to the front ceiling of the remote classroom. Each camera showed a view that was approximately the width of a students' 60" wide worktable. A VideoTek brand routing-switcher configuration (Models RS-10ARC-L-SW and RSCC-1) used the closure of a set of contacts in a Shure brand (Model 550L) push-to-talk microphone to switch the outgoing video to show the individual student workstation where that microphone was located. In addition to the four microphones located at each of four student workstations, two additional microphones were located on left and right tables at the front of the classroom. These microphones activated a view of the entire left and right half of the classroom shown by two other cameras on the front ceiling of the room. Students at workstations near the front of the room quickly learned that pressing one of these front microphones would return the outgoing video from a view of an individual student who had recently spoken to a larger view of the classroom.

Equipment Setup and Storage Logistics. Each of the connector laboratories involve an extensive array of small items. An ST or rotary splice repair kit is contained in a large suitcase with foam cutouts that hold various tools, supplies, and other equipment. The fiber optic repair course used nine ST repair kits and nine rotary splice repair kits, one for each student and the instructor. The Hughes connector laboratory uses several items from these kits and a number of other tools. These laboratories required numerous other consumable supplies such as connectors, cables, wipes, alcohol, adhesives, and polishing paper. Taken together, this array of small items required at least a full table for each student, as well as storage space for the items not being used at the moment. The amount of space required within the classrooms was also taxed by the presence of

the test equipment and fiber optic system carts (i.e., a total of four system carts, five OTDRs, and four OLTSs). Since VTT classrooms are used for other courses, this array of items had to be moved in and out of the classrooms for each class convening. Thus, when this laboratory course was not being convened, space in a small room was required to store the suitcases and supplies, as well as the test equipment and fiber optic systems. The logistics in conducting this laboratory course by VTT therefore required some extra effort with regard to setting up a class each time and then to subsequently store the equipment between classes.

Results

ST and Rotary Splice Connector Laboratories

Data on individual students collected during the ST and rotary splice connector laboratories consisted of observer records of procedural errors, observer work product and safety ratings made at the completion of the task, and records of help or assistance given to students. During the first laboratory, students installed two ST connectors, one on each end of the same cable. During a second laboratory, students installed a rotary splice connector midway through the same cable that had been used during the ST connector laboratory. As a consequence of this sequence, experience on the first task might be expected to benefit the second task and result in fewer problems and errors.

Connector Task Errors

Scoring and Categorization Methods. Observer error counts and comments were exhaustively listed, individual errors were identified, and then several aggregate categorizations were derived. The term "error" as used here included explicit violations of the procedure, damage to the work product, safety violations, and a variety of other problems or difficulties that were encountered by students during the procedure. Multiple instances of the same error for a given student were generally scored for as many times as the student made the error (e.g., two instances of the same error were counted as two errors for that student in the scoring). However, there were several cases where multiple instances of an error were counted as only one error when it was apparent that raters differed somewhat in their marking strategies or when two errors were highly related.[5]

Student task performance was analyzed in several ways using the following terminology. *Individual errors* were the lowest level of the data and counts of these errors were used as the basis for developing three error categorizations (individual errors are shown in Tables G-2 and G-3 of Appendix G). These categorizations allowed several questions about task performance to be answered and also served the purpose of aggregating errors with low frequencies so that stable statistical estimates were possible. The categorizations examined errors in terms of *sequential*

[5]For example, errors for disposing of the fiber correctly and having laid out masking tape to dispose of the fiber implied one another. Another example of a tightly related set of errors was putting the boot, sleeve, and masking tape on the cable at the start of the ST procedure.

phases of the procedure, the *type of error*, and by a meaningful *grouping* of the error types (e.g., critical to the work product).

Errors by Sequential Phase. The linear sequence of individual errors during the procedure was divided into four broad sequential phases. The phases were divided by logical breaks in the task and the steps within each phase were internally related in that they were directed at reaching a subgoal. For the ST connector, the four phases were as follows:

Phase A: Fiber preparation removal of jacketing and buffer in correct lengths.
Phase B: Epoxy preparation, injecting epoxy, inserting fiber, installing cable sleeve, crimping connector, and curing epoxy in oven.
Phase C: Cleaving/scoring fiber, detaching and disposing of fiber fragment.
Phase D: Initial and final polishing and testing product.

For the rotary splice connector, the four phases were as follows:

Phase A: Fiber preparation removal of jacketing and buffer in correct lengths.
Phase B: Adhesive and ferrule preparation, injecting adhesive, inserting fiber, curing adhesive under ultraviolet lamp.
Phase C: Cleaving/scoring fiber, detaching and disposing of fiber fragment.
Phase D: Initial and final polishing, splice assembly with matching gel, and testing product.

Figure 4 shows the ST and rotary splice connector task errors in terms of the four sequential phases. All but one individual error is included (40 of 41 ST errors and 38 of 39 rotary errors are used). The individual error of not wearing safety glasses is omitted because these errors were not easily located to a step and were partially based on observer comments when making the post-procedure work product ratings.

The percent of errors over the phases of the procedure was similar for the two connectors. The ST connector errors for Phases A, B, C, and D were distributed 36%, 17%, 18%, and 29%; and the rotary splice connector errors were distributed 35%, 15%, 19%, and 31%. Thus, there are somewhat more errors during the preparation of lengths Phase (A) and the polishing Phase (D). However, the 18-19% of errors for the cleaving Phase (C) is notable because this phase is relatively brief compared with the other phases of the procedure.

It is apparent from Figure 4 that the average errors for the three treatment groups are very similar over the phases of the procedure in all but one instance. There are over twice as many errors for traditional students as for VTT students during the first phase of the ST procedure. Inspection of the individual errors contributing to this result revealed that most were related to general technique and cleaning (e.g., failing to wipe the fiber with alcohol, wiping it several times, and allowing the fiber to touch the work surface). As discussed below, these errors may be related to not having seen the videotape. Statistical analysis of this same data will be reported below in analyzing differences in the type of errors for the groups.

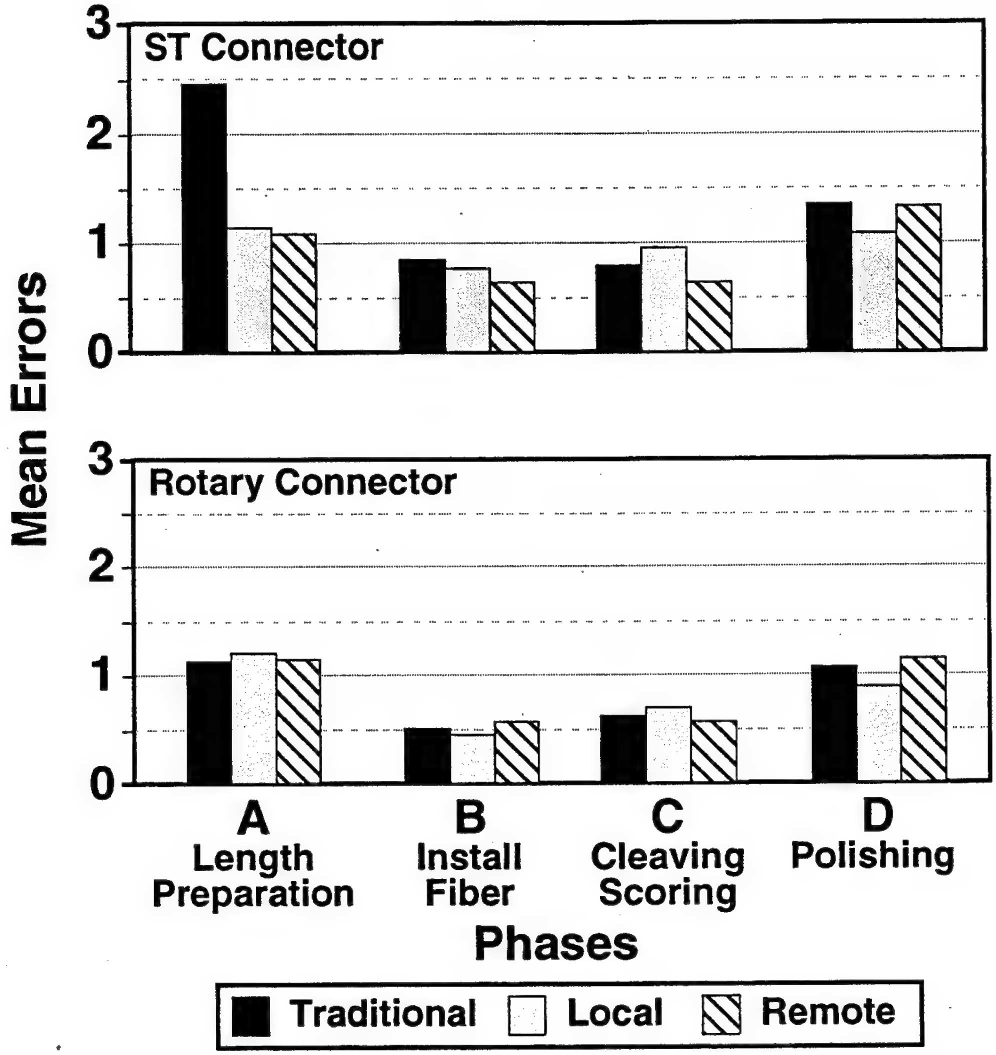

Figure 4. Average errors by sequential phases of the ST and rotary splice procedures.

Examples of Common Errors. Appendix G shows the average errors for each of the individual errors for all 50 students combined. This breakdown may be useful to instructors in developing lecture points that direct student attention to typical problems they will encounter. Examples of the most frequent errors are listed below. They comprise approximately a quarter of the individual errors, each committed by about 15% or more of the students. Early in the procedure, the most common errors were failing to put the boot and sleeve on the cable at the start of the ST procedure, failing to remove enough buffer with the buffer removal tool, breaking the fiber while using the buffer removal tool, allowing the fiber to touch the work surface, and not placing the cable in a slot of the cooling block. During cleaving, scoring the fiber several times and breaking

the fiber during cleaving were most common. Common errors at the end of the procedure included failing to clean the polishing plate or paper with alcohol, failing to clean the connector prior to inspecting it, discovering a shattered or scratched ferrule face during inspection, repolishing to overcome a problem such as excess epoxy or adhesive, and difficulty deciding when the polish was completed. Failing to wear safety glasses was also a more frequent error and virtually every noted instance was included in this scoring, no matter how slight. Many of these were minor instances late in the procedure during polishing when fiber fragments were no longer present. Observer ratings reported later indicated a consistent problem in about 6% of the students.

Grouping Errors by Type. Errors of the same *type* were individual errors that were the same, similar, or related, but which occurred at different points in the sequence of the task. A predominate feature of an error was chosen to resolve a few instances where an error could be classified as more than one error type, but subsequent clustering of the errors left all of these within the same group of errors (e.g., some cleaning or general technique behaviors). A total of 13 common error types were derived from the 41 individual ST errors and 39 individual rotary errors. These included the error of failing to wear safety glasses that was not included in the previous analysis of sequential phases. The individual errors that comprised these error types are given in Appendix G.

The 13 error types were clustered into four broad *error groups* thought to reflect important features of these tasks. The primary motive for this taxonomy was to isolate errors judged to be more serious from other less critical errors having to do with general technique or characteristic problems encountered. The four error groups were: (1) errors that were critical to a successful work product; (2) fiber care, mishandling, and safety; (3) less severe problems in general technique, length preparation, and cleaning practices; and (4) difficulties encountered during polishing and in deciding when the polish was completed, including cleaning that specifically affected completing the polish (i.e., failing to clean the connector prior to inspecting the polish). The 13 types of errors within these error groups are given in Table 2.

Averages for the error groups are shown in Figure 5 (averages for the 13 error types are in Tables G-4 and G-5 of Appendix G). Overall, there was almost one less error on the second of the two tasks (rotary) than on the first task (ST), suggesting some benefit of the first laboratory on the second. For all 50 students combined, there was an average of 4.6 errors for the ST connector (232 total) and 3.7 errors for the rotary connector (168 total). This decline was primarily in the general technique and polishing error groups. The average number of errors overall by the traditional, local, and remote groups on the ST connector were 5.7, 4.2, and 3.9, and on the rotary connector were 3.8, 3.6, and 3.8. Figure 5 shows that the level of errors for the three treatment groups was similar over the error groupings in all but one instance. As with the previous categorization of errors by phase, the traditional group shows more errors on the ST connector task and the present analysis shows these to be in the technique, length, and general cleaning category.

The highest average level of errors in Figure 5 tend to be in the general technique, length, and cleaning category and the lowest level is in the polishing category. The percentage of all errors for each of the two connectors was generally similar for the error groups. About half of the errors are in the two more serious categories of being critical to the work product and fiber care and safety (ST 44.4%; rotary 55.3%). About a quarter of the errors were critical to the work product (ST 23.7%; rotary 26.3%), and the most common error in this category was breaking the fiber (ST 14.2%; rotary 9.1%). Fiber care, safety, and safety glasses comprised approximately another

quarter of the errors (ST 20.7%; rotary 29.0%), and most commonly concerned fiber care (ST 11.2%; 12.4% rotary). Less serious technique, length, and cleaning errors (ST 40.5%; rotary 33.3%), were predominately errors of general technique (ST 23.7%; 19.4% rotary). Difficulties during polishing (ST 15.1%; rotary 11.3%) tended to diminish on the second task for cleaning (ST 10.3%; rotary 3.8%) and increase slightly for difficulty in completing the polish (ST 4.7%; rotary 7.5%).

Table 2

Connector Errors by Group and Type Within Group

Critical to Work Product Group:
- Broken fiber
- Connector damage, not secure, or broken
- Shatter shown, scratched or damaged ferrule face
- Technique critical to product
- Length preparation problem critical to product

Fiber Care, Mishandling, and Safety Group:
- Fiber care and mishandling
- Safety
- Safety glasses at any step

Technique, Length Preparation, General Cleaning and Liquids Care Group:
- Technique, general technique not critical to product
- Length preparation problem
- General cleaning and care with liquids

Polishing and Cleaning Directly Affecting Polish Decision Group:
- Polishing, repolishing to overcome problem, and difficulty deciding when polish was completed
- Cleaning directly affecting polish (cleaning connector before inspecting polish)

Similar results were found for both connector tasks when a two-way analysis of variance (ANOVA) was conducted with the three treatment groups as one factor and the four error groups as a second factor. For the rotary connector, there was a significant main effect for differences among the error groups, $F(3,141) = 5.16$, $p < .01$, but there was no significant difference among treatment groups, $F(2,47) = 0.01$, $p > .05$, or for an interaction between treatment and error groups $F(6,141) = 0.40$, $p > .05$. For the ST connector, there was a significant main effect for differences among the error groups, $F(3,141) = 6.91$, $p < .01$, but there was no significant difference among treatment groups $F(2,47) = 1.41$, $p > .05$, or for an interaction between treatment and error groups $F(6,141) = 1.11$, $p > .05$. Although the traditional group shows a higher level of technique and cleaning group errors for the ST connector, the effect was not strong enough to be significant relative to the variability within groups. Inspection of the 13 individual error types (see Appendix G) revealed that the difference between groups was primarily due to the general cleaning error type (average errors were 0.94 traditional, 0.31 remote, and 0.13 local). Selecting only this cleaning error type for analysis, the difference between groups was significant, $F(2,47) = 3.72$, $p < .05$.

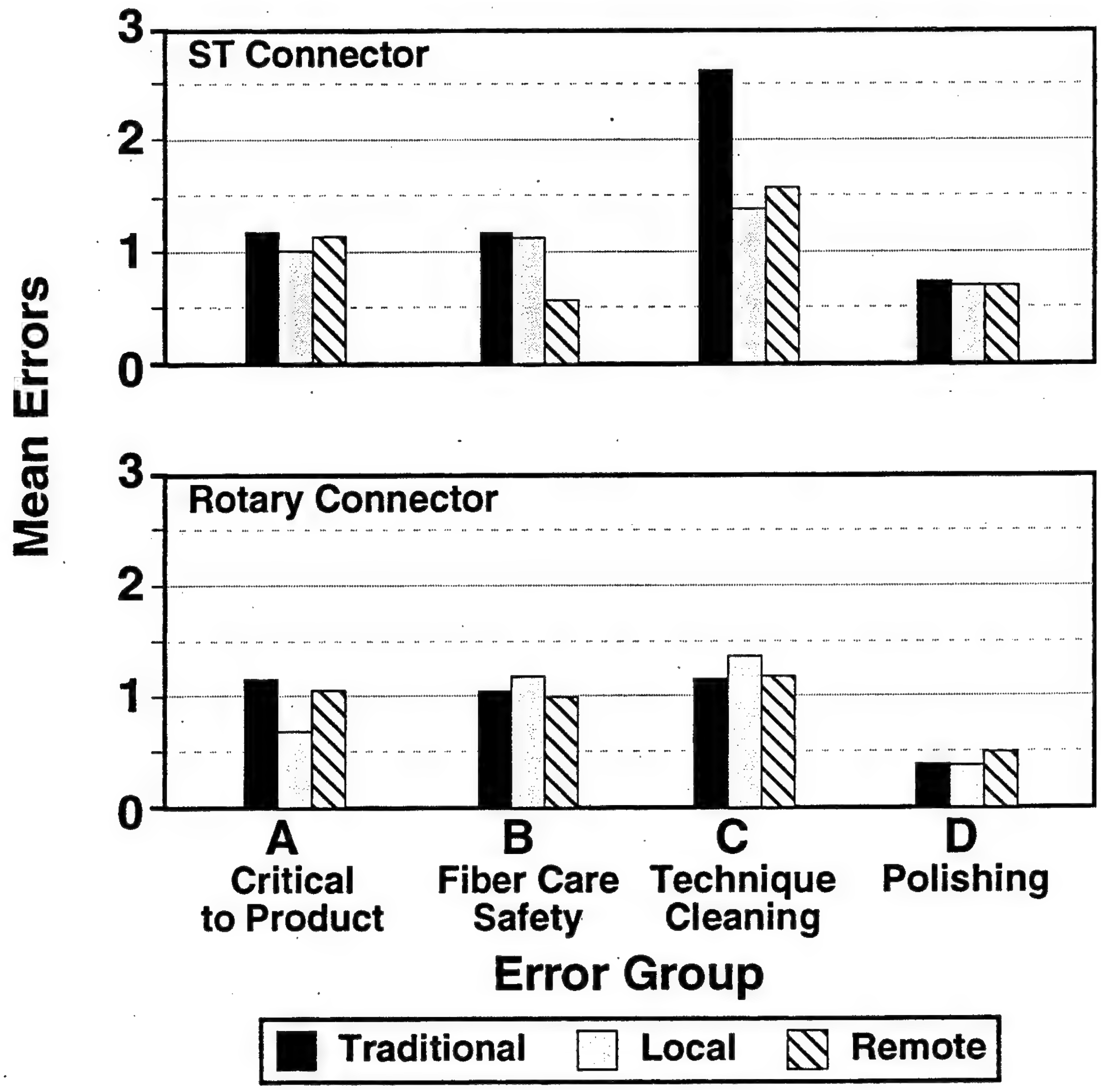

Figure 5. Average errors by error group for the ST and rotary splice procedures.

The greater errors for the traditional group in the technique, length, and cleaning error group may have arisen from a combination of factors: (1) the traditional group only saw one demonstration of the procedure, whereas the VTT groups saw it twice, once on videotape and once by the live instructor, (2) the videotape emphasized several techniques that counted as errors if they were not performed (note that the error check list was derived from the script of the videotape). The second of these explanations is similar to that offered by Simpson et al. (1992) in interpreting the results from a damage control laboratory. A hands-on laboratory experience yielded a small overall advantage over a videotape demonstration on most measures. However, the laboratory group made more errors on one task for certain procedural steps that were apparently conveyed better for those watching a videotape than those in the conventional laboratory.

Taken together, there was no indication that delivering the course by VTT impaired the remote site students in terms of errors in performing the connector tasks. A small increase in errors for the traditional group in terms of some nonserious techniques such as cleaning was hypothesized to result from a combination of having seen the procedure once instead of twice and the use of an error check list emphasizing techniques shown in the videotape.

Observer Work Product and Safety Ratings

The purpose of the observer ratings was to summarize various aspects of student performance at the end of the procedure. These ratings and the previously discussed observer error checklist were intended to be complementary sources of information. The ratings ensured that important aspects of the task would be covered in circumstances where errors became apparent later and had been missed by observers earlier in the procedure.

Work Product Ratings. At the completion of the connector task, actual light loss readings were recorded for each end of the cable and observers rated eight aspects of each student's work (Appendix D presents the rating items, scales used, and raw frequencies). All work product items were rated on a three point scale that assigned higher numeric values for acceptable aspects of the work product.[6]

As can be seen in Figure 6, most ratings are high and there are generally small differences between the treatment groups. The only discernible pattern over a few of the rating items is a slightly higher rating for the local group compared with the other groups. Rating Items 4 through 8 are slightly lower for the rotary connector than they are for the ST connector. This pattern to some extent reflects several circumstances, such as the greater difficulty in polishing away the harder UV adhesive and instances where the more fragile rotary connector ferrule was broken and the task could not be completed. Combining all eight ratings for the ST connector, 81.25% of the ratings were in the highest acceptable category, 12.25% were in the intermediate category, and 6.5% fell in the lowest category. For the rotary connector (combining only the first eight ratings in Figure 6), 77.5% of the ratings were in the highest acceptable category, 14.0% were in the intermediate category, and 8.5% fell in the lowest category.

An analysis of variance was computed for each rating item to test for significant differences among the three treatment groups. Analysis of variance F ratios for each of the rating items as ordered in Figure 6 were as follows for the ST Connector: $F(2,47) = 0.44, 0.90, 1.32, 1.3, 0.29, 2.31, 2.26, 1.32$; and for the rotary connector: $F(2,47) = 0.21, 0.06, 1.39, 1.20, 1.0, 0.65, 4.49^*, 0.26, 0.03$. None of these F ratios were significant ($p>.05$), except for Item 7 on the rotary connector ($^*p<.05$), where a Tukey HSD test showed that the traditional group was scored significantly lower than the local group on cleaning practices.

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[6]The scale for the first three rating items assigned a 1 when both connector ends suffered the problem, a 2 when one of the two ends had a problem, and a 3 when there was no problem with both connector ends. The scale for rating Items 4 to 7 assigned a 1 when there was a problem, a 2 for marginal, and a 3 when there was no problem. The light loss readings for Item 8 were rated 1 if both ends were unacceptable, a 2 if one connector end was unacceptable, and a 3 if both ends were acceptable.

The ultimate practical criterion for the connector work was whether the work product had an acceptable amount of light loss as measured by the optical loss test set (OLTS). The instructor judged the ST connector to be acceptable when there was less than -0.5 db loss through the two connectors on either end of the cable (i.e., -0.5 to 0.0 was acceptable). The instructor judged the rotary connector to be acceptable when there was less than -1.0 db loss (i.e., -1.0 to 0.0 was acceptable). Whereas students used the same cable on which they had previously installed ST connectors, the -1.0 db criterion was based on the sum of the -0.5 db loss allowed for the ST connectors and another -0.5 db loss for the rotary connector installed midway through the same cable. In attempting to achieve an acceptable reading for rotary connectors found to exceed this -1.0 db criterion during the laboratory, students were allowed to reevaluate their work in terms of a -0.5 db criterion after subtracting out readings for previously installed ST connectors that were known to be bad. However, were this difference method used for all students, some rotary connector readings would not be acceptable in those instances where the previous ST reading was very good and the rotary connector by itself had excessive light loss. Therefore, a second scoring method was used here, which used the difference method for all students in order to uniformly judge all rotary readings independent of the ST connector. In Figure 6 and Table 3, there are two versions of rating Item 8, the method actually used during the student laboratory (L) and the difference (D) method. As can be seen in Figure 6, the more stringent difference method shown in rating Item 8(D) results in lower rated performance compared with the student laboratory method shown in Item 8(L), but has little effect on the differences between treatment groups.

Table 3 shows the within group percentage of students in three categories: acceptable readings from both ends of the cable, acceptable readings from one end only, and unacceptable readings from both ends of the cable. For the ST connector, the traditional group has an overall higher level of an acceptable product on both ends. The reverse is true for the rotary connector, where remote and then local students perform best and the traditional group performs the worst. As noted earlier, there were no significant differences between groups for either connector in terms of the average ratings (this conclusion would remain the same had the data been analyzed by the three categories with a Chi Square test). Overall groups, 70% of the ST connectors have fully successful bidirectional readings. Success is lower for the rotary connector, where 64% are successful by the student laboratory scoring method, and 48% are successful by the more stringent difference method. With both ST and rotary connectors, instances where readings from both directions are unacceptable are over twice as likely as instances where there is one good and one bad reading. The fully successful category scored by the difference method represents the most stringent criterion that could be expected on the job, where readings would be expected to be less than -0.5 db for both ends and there was no broken ferrule or other damage for either end. The lower fully acceptable ratings on the rotary connector are partially due to broken ferrules preventing a reading.

Overall groups, the median light loss readings for connectors with acceptable bidirectional readings was -0.21 db for ST connectors and -0.63 db for rotary connectors (-0.21 db using the difference method). For fully or partially unacceptable readings where a reading could be taken (e.g., not possible because of a broken ferrule), the median readings were -3.31 db for the ST connectors and were -2.66 db for the rotary connector (-0.79 db using the difference method).

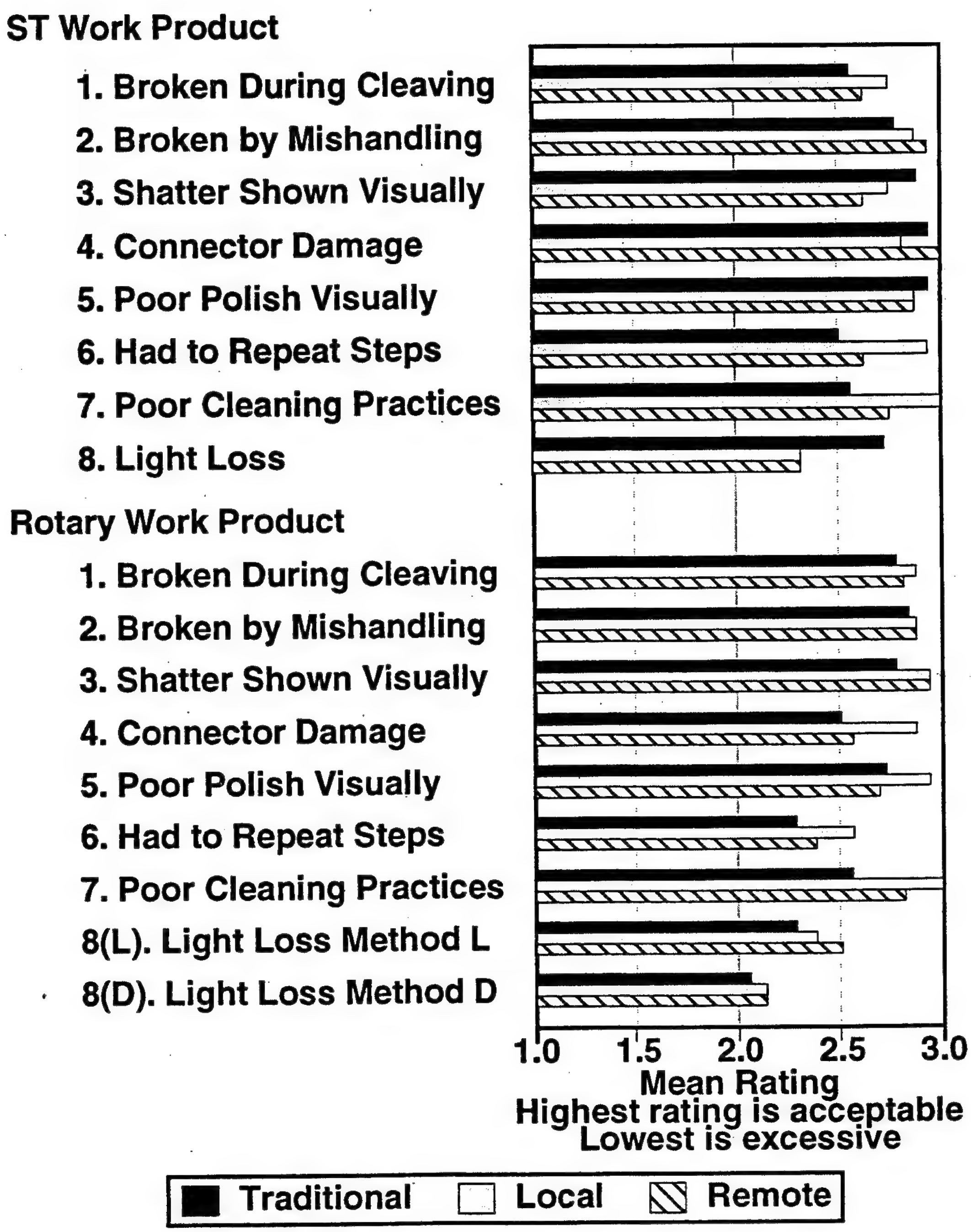

Figure 6. Observer work product ratings for ST and rotary splice connector laboratories.

Table 3

Percent of Students with Acceptable and Unacceptable Light Loss Reading for ST and Rotary Splice Connectors

	Treatment Group			
Connector and Measure	Traditional	Local	Remote	All Groups
ST Connector				
Both ends acceptable	83.3	62.5	62.5	70.0
One acceptable/one unacceptable	5.6	6.3	6.3	6.0
Both ends unacceptable	11.1	31.25	31.3	24.0
Rotary Splice Connector				
Laboratory Scoring Method (L)				
Both ends acceptable	55.5	62.5	75.0	64.0
One acceptable/one unacceptable	16.7	12.5	0.0	10.0
Both ends unacceptable	27.8	25.0	25.0	26.0
Difference Scoring Method (D)				
Both ends acceptable	44.4	50.0	50.0	48.0
One acceptable/one unacceptable	16.7	12.5	12.5	14.0
Both ends unacceptable	38.9	37.5	37.5	38.0
Total Number of Students	18	16	16	50

Note. Percentages are within each treatment group and for all treatment groups combined. ST light loss readings were acceptable at -0.5 db or less (i.e., -0.5 to 0.0). In the laboratory scoring method (L) for rotary splice connectors, acceptable readings were -1.0 db or less (i.e., -1.0 to 0.0) except for occasional cases where previous unacceptable ST connector readings were subtracted and a -0.5 db criterion was used. In the difference scoring method (D), ST connector readings were subtracted from all rotary splice readings and judged acceptable by the -0.5 db criterion (i.e., -0.5 to 0.0).

Safety Ratings. Figure 7 shows the average safety ratings made by observers for the ST and rotary splice connector laboratories (Appendix D presents the rating items, scales used, and raw frequencies). Only five of six ratings are shown because canned air was infrequently used during the laboratories (very few ratings were made on Item 3 for canned air use and all were in the acceptable category). Acceptable ratings ("almost always") were assigned the highest value of 3, a "mostly" marginal rating a 2, and the lowest rating a value 1 ("rarely").

The average level of all ratings is high (between 2.5 and 3.0), there are negligible differences among the treatment groups, and there is no consistent pattern for a group over the ratings. An analysis of variance for each item showed no significant between group difference on any of the ST or rotary splice ratings. Analysis of variance F ratios for the rating items as ordered in Figure 7 were, respectively, as follows for the ST Connector: $F(2,47) = 0.07, 0.67, 2.07, 0.09, 0.68$; and for the rotary connector: $F(2,47) = 0.05, 0.22, 1.66, 0.16, 2.28$, all $ps > .05$.

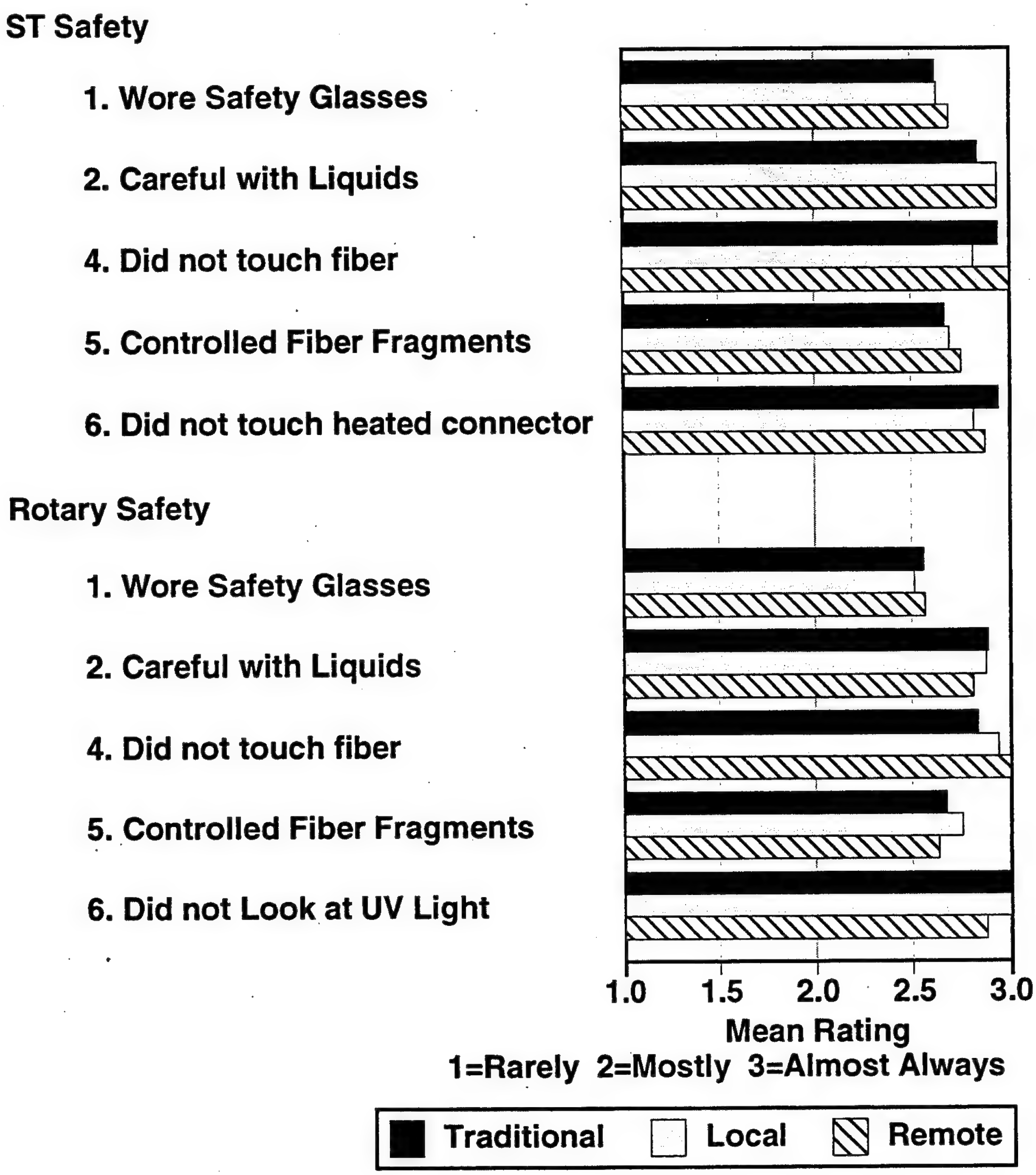

Figure 7. Observer safety ratings for ST and rotary splice connector laboratories.

The percent of ratings in each of the three rating categories differed by less than 2% between the ST and rotary connector ratings. Combining all five ratings for both connectors, 82.8% of the ratings were acceptable "almost always" ratings, 14.6% were "mostly" ratings, and 2.6% fell in the lowest category ("rarely"). Of the five ratings, wearing safety glasses and controlling fiber fragments are rated slightly lower than care with liquids, touching the glass fiber, and care with heating or using the UV light on the connector. Combining both connectors over all groups, about 6% of the students were given the lowest rating on wearing safety glasses and about 7% were given the lowest rating on controlling the fiber fragment.

Taking the findings for both observer safety and work product ratings together, there were no consistent group differences and there was no detrimental effect for remote students compared with the other groups.

Help During Connector Laboratories

The average help or assistance per student during the connector laboratories is shown in two different ways in Figures 8 and 9. Figure 8 shows help over the phases of the ST and rotary procedures and Figure 9 shows the type of help that was initiated by the participants as well as the overall average combined over the categories. Overall, there are more instances of help during the first laboratory (ST) than during the second laboratory (rotary). However, it is primarily the traditional and local students that have a lower level of help during the second laboratory, while remote students show only a slight decline.

A one-way ANOVA was used to test the overall differences between groups because there are low frequencies resulting in large differences in variability when the data are broken down by the phase and participant categories. The slight trend for an overall greater level of help for remote students for the ST laboratory was not significant, $F(2,47) = 0.48, p > .05$. For the rotary laboratory, the overall average help for remote students is a little less than twice as high as in the other groups, and the difference between groups is significant, $F(2,47) = 3.39, p < .05$.

Figure 8 shows that help during the phases of the two connector procedures is least frequent during the cleaving in Phase C, and both ST and rotary procedures share a high level of help during the polishing Phase D. Helps during the first two phases appear to be less frequent during the second laboratory (rotary) compared with the earlier ST laboratory. For the rotary splice connector laboratory, the highest level of help for all groups is during the polishing Phase D, which may reflect the greater difficulty in polishing away the hard UV adhesive and deciding when the work product is completed. Remote students have only slightly more helps during the first three phases and then many more helps than the other groups during the polishing Phase D.

Figure 9 shows the level of help as initiated by students and by the instructor or facilitator. The most frequent instance of help was where students initiated help from the instructor or facilitator (the bars in the figure for remote students show a relatively even distribution of help sought from the instructor [I] and facilitator [F]). For the ST connector, there appears to be a slightly greater level of student to student help for the remote group, but this difference was not significant by a nonparametric test (Kruskal-Wallis $H(2) = 3.69$, $p > .05$). For the rotary connector, the groups appear to differ in the two student initiated help categories. The difference between groups on student initiated help to the instructor or facilitator is not significant ($H(2)=2,52$, $p>.05$), but the treatment groups do differ significantly in terms of student to student help ($H(2)=17.53$, $p<.01$).

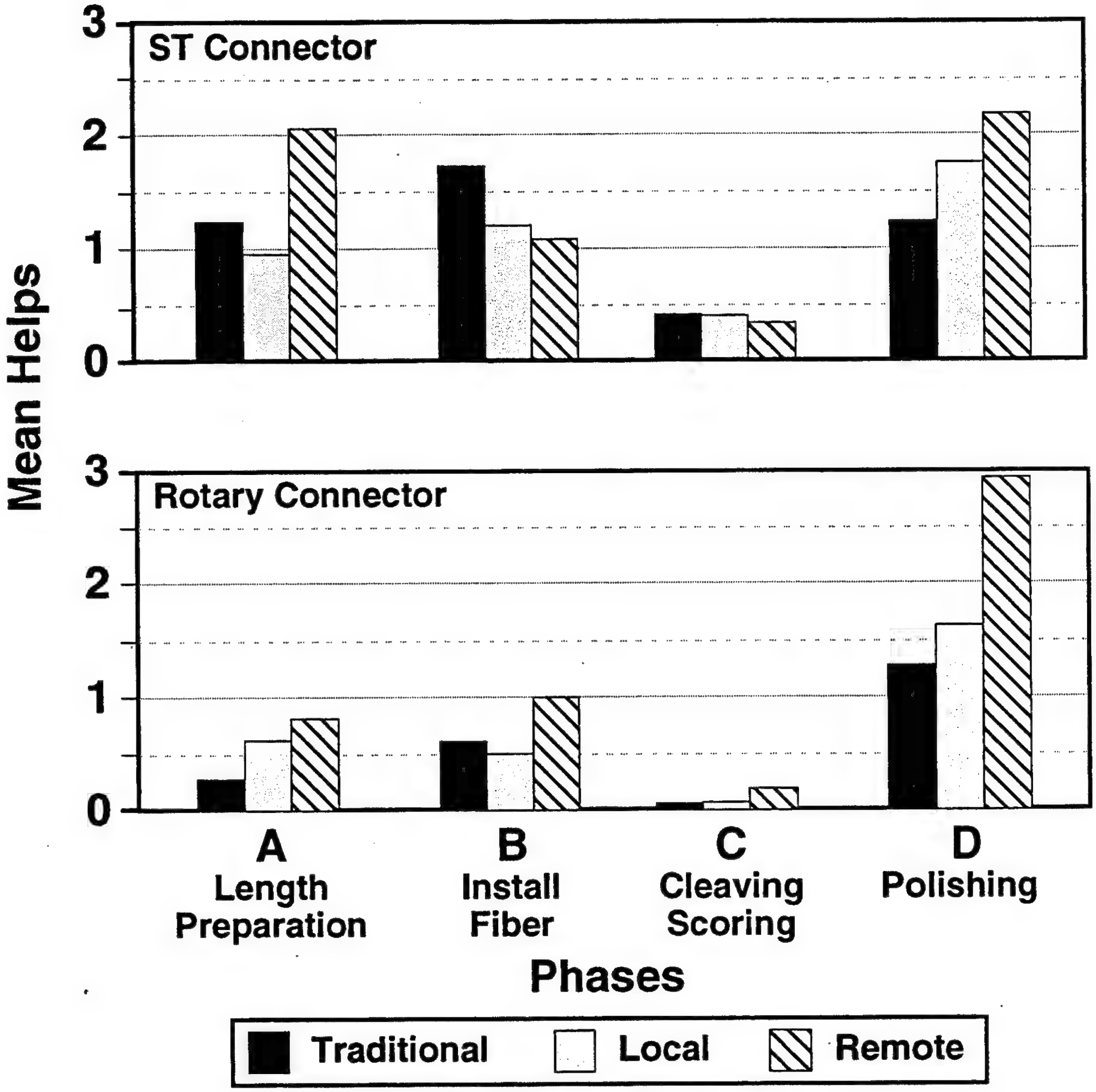

Figure 8. Student help and assistance during phases of the connector tasks.

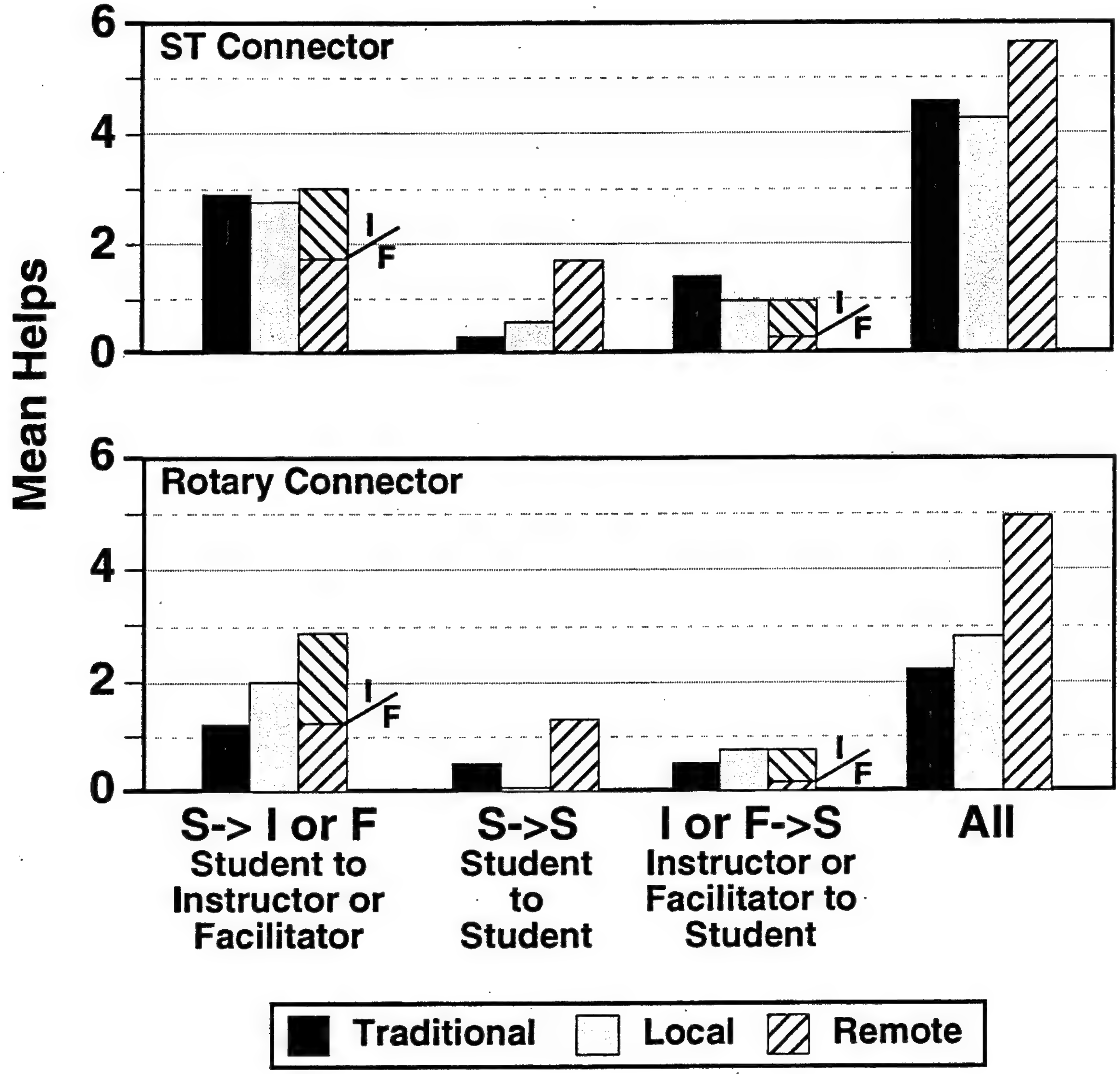

Figure 9. Student help and assistance by type of help during connector laboratories.

Troubleshooting Performance Test

The troubleshooting performance test required students to successfully locate a prearranged fault in two different fiber optic cable systems. Students who did not successfully locate the faults in the first two systems attempted were required to continue to a third or fourth system to reach the criterion of two successfully solved systems. Student success in reaching the criterion resulted directly from the instructor's judgment of the student's work, which involved personal consultation with the student. For each test system, students completed a form that directed their progress through a series of steps. The initial steps consisted of taking two readings: using the OLTS meter to obtain a total system loss measurement, and using the OTDR to obtain a view of the junction sites over the system. Based on this information, students listed the possible faults in the system. Students then tested different junction sites within the system to locate the fault and recorded the fault on the form. Students then listed possible corrective actions for the fault and identified the one corrective action to take, based on the nature of the fault.

Test Performance

All but one student in each treatment group successfully solved the system fault in two successive systems. One student in the local group and one student in the remote group required three systems to solve two faults. One student in the traditional group solved only one system fault out of four systems. Table 4 shows that the average number of systems attempted was only slightly greater in the traditional group than in the VTT groups. An analysis of variance showed this difference was not significant, $F(2,47) = 0.11$, $p > .05$. The percentage of systems attempted for which students correctly solved the fault was 4.8% lower in the traditional group than in either of the VTT groups, a difference that was not significant by a test of proportions expressed as Chi Square (Fleiss, 1981, p.139), $\chi^2(2) = 1.47, p > .05$. Taken together, student success in solving faults on the performance test was very similar among the treatment groups.

Several other measures derived from the performance test were examined for differences between the treatment groups that might reveal any disadvantage for remote students. Because the traditional laboratory testing situation involved interactive student-instructor exchanges during the test, performance on the second of the two systems was examined for any learning benefits resulting from experience with the first system. In order to conduct two-way analyses of variance (ANOVA), only the data from the first and second systems was used (i.e., 100 of the 104 tests).

Students listed possible fault causes following the initial system measurements with the OLTS and OTDR, but before conducting further troubleshooting at specific sites in the test system. Student responses were scored as being correct if specific system sites were identified (e.g., "connector IC-4 #64" was correct, but "bad connector" was scored incorrect). Over all groups, an average of 3.4 causes were listed by students, and about a third of these responses were correct. Table 4 shows that the average percent correct of possible fault causes was similar among the treatment groups and that there was little improvement from the first to the second test system. A two-way ANOVA showed no significant main effect differences between the treatment groups or between the first and second test, and there was no significant interaction between these two factors (all Fs $< 1, p > .05$).

Following the determination of the fault, students listed possible corrective actions for the fault, and then identified one corrective action appropriate to the circumstances of that system. The corrective actions were generally of two types: use an alternate path or repair the source of the fault. In some test systems the fault could be repaired immediately, but in others the repair would have taken some time and so the use of an alternative path would return the system to operation immediately. The percent of the two types of actions to correct the fault listed by students was about 50% overall (i.e., on average, one of the two alternatives was given). However, Table 4 shows knowledge of these two concepts improved from the first to the second system. A two-way ANOVA showed a significant main effect for the difference between the first and second system, $F(1,47) = 8.13$, $p < .01$, but no significant main effect for treatment groups or for an interaction between groups and the two tests (Fs $< 1, p > .05$). Combining treatment groups, performance was 17% higher on the second test than the first test. This increase in knowledge of the two concepts suggests that students had gained the knowledge as a result of experience with the first system and/or through interactions with the instructor.

Table 4

Troubleshooting Performance Test Results

Measure and Group	Traditional	VTT Local	VTT Remote
Number of students	18	16	16
Total number of systems attempted	38	33	33
Number of systems with correct solution*	35	32	32
Average systems attempted per student			
Mean all systems	2.11	2.06	2.06
Standard Deviation	0.47	0.25	0.25
Percentage success for system attempted	92.1	96.9	96.9
Mean percent correct possible fault causes listed by student based on initial readings			
Test System 1 (35.6% overall)	33.8	38.9	34.4
Test System 2 (36.1% overall)	29.3	35.8	44.0
Both systems	31.5	37.4	39.2
Mean number responses both systems	3.7	3.3	3.4
Mean percent correct of two types of corrective actions listed to correct the fault			
Test System 1 (46% overall)	38.9	46.9	53.1
Test System 2 (63% overall)	63.9	65.6	59.4
Both systems	51.4	56.3	56.3
Percent students giving instructor's answer for corrective action for fault			
Test System 1 (48% overall)	38.9	50.0	56.3
Test System 2 (56% overall)	50.0	62.5	56.3
Both systems	44.4	56.3	56.3
Mean time to solve fault (minutes)			
Test System 1 (47.7 overall)	47.0	48.3	47.8
Test System 2 (37.2 overall)	35.2	33.8	42.7
Both systems	41.1	41.0	45.3

*All but one student in each group successfully solved the system faults in two successive systems. One local and one remote student required three systems to achieve success on two systems. One traditional student required four systems and successfully solved only one.

When students were asked to select the best single corrective action for the fault, only about half of the students gave the answer that was judged best by the instructor. The percent of students giving the answer judged best by the instructor was only slightly greater on the second of the two test systems and remote students scored well compared to the other groups. The largest difference among treatment groups was on the first test and was not significant by a test of proportions expressed as Chi Square (Fleiss, 1981, p.139), $\chi^2(2) = 1.06, p > .05$. The largest difference between

the first and second systems was 12.5% in the local group and was also not significant by a test of proportions, $\chi^2(1)=0.12$, $p > .05$.

Test Time

Students were allowed an hour to determine the fault in a test system. The amount of time required to complete the test was recorded by observers as an index of performance. Figure 10 and Table 4 show that students required less time on the second test than they did on the first test. An ANOVA showed that this difference between the two tests was significant, $F(1,47) = 18.34$, $p < .01$, but revealed no significant main effect difference between the treatment groups, $F(2,47) = 0.65$, $p > .05$. The interaction between the two tests and the treatment groups was not significant, although Figure 10 suggests a trend in this direction, $F(2,47) = 1.25$, $p > .05$. The three groups took almost the same average amount of time to complete the first test (47 to 48 minutes). The second test was completed in 11.8, 14.4, and 5.1 fewer minutes for the traditional, local and, remote groups respectively. The remote group took 7 to 8 minutes longer than the other groups on the second test. Slightly longer test times might be expected for remote students because they had to use the VTT system or telephone to communicate with the instructor. However, this trend would be expected to be present on both the first and second tests. Taken together, students appear to become more adept at solving the faults following the experience with the first system, and remote students show a slight trend towards longer test times on the second test.

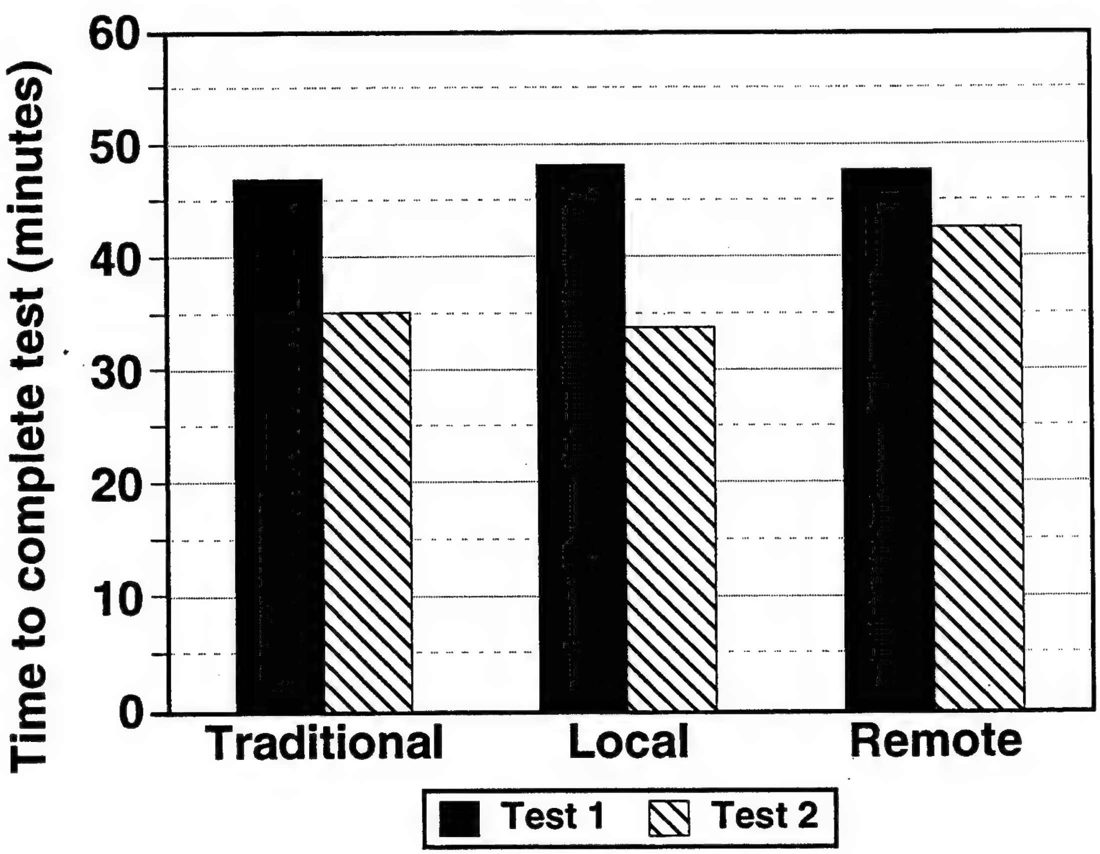

Figure 10. Time to complete first and second student performance tests.

Help During Test

Assistance given to students during the performance tests was primarily initiated by the student. Students initiated 80% of the instances where help was sought from either the instructor or VTT facilitator over all groups combined. The remaining 20% of the instances resulted from the instructor or facilitator initiating assistance given to students (by group, this help was 26% traditional, 15% local, and 15% remote). Whereas traditional and local students could only receive help from the instructor, remote students could receive help from either the instructor or facilitator. For instances of remote student help, 50% were initiated by the student toward the facilitator and 35% were toward the instructor, with the remainder being initiated by the facilitator (13%) and the instructor (2%).

Figure 11 shows the average number of help instances in the three treatment groups on the first and second test system. In parallel with the test times (i.e., previous Figure 10), students also required less assistance on the second of the two tests. An ANOVA showed that there was a significant decline in helps from the first to second test, $F(1,47) = 33.8$, $p < .01$. There was no significant main effect difference between the treatment groups $F(2,47) = 0.70$, $p > .05$, and there was no interaction between groups and the two tests $F(2,47) = 0.83$, $p > .05$.

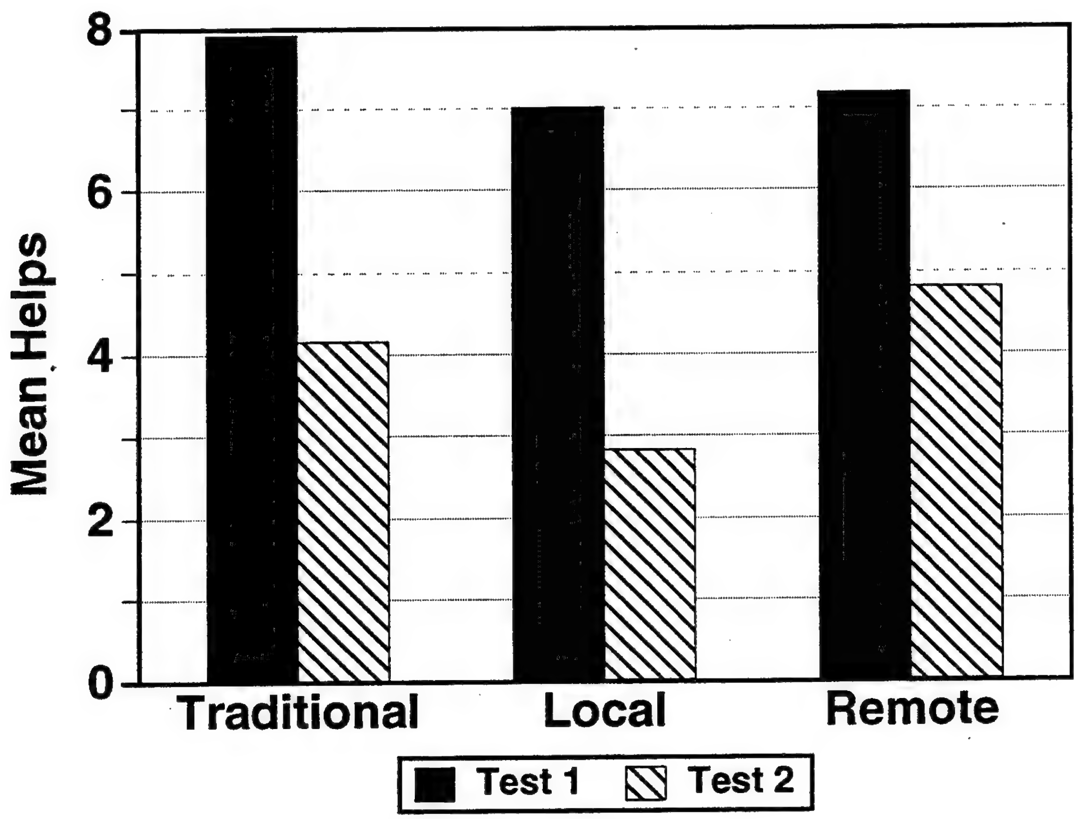

Figure 11. Help and assistance during first and second student performance tests.

Descriptive categories of the kind of help during the performance test showed a generally similar pattern for the treatment groups. The most frequent type of help concerned trouble shooting logic, such as when a student had obtained relevant data but did not understand how to interpret it and arrive at a solution. Overall groups, 54% of the help concerned trouble shooting logic. The other type of help during the test was evenly divided between that concerning the use of the OTDR/ OLTS test equipment (22%), and that concerning the entries that were to be made on the system record form (24%).

Other Descriptive Findings for Student Laboratories

Several other sources of data were collected during student laboratories. Analyses of these data were primarily descriptive because the number of cases was small when observations were recorded for the whole classroom or for teams rather than individuals. These are reported below for only the four convenings of the local and remote classes.

Hughes Connector/Backshell Laboratory

The student laboratory with the Hughes connector and backshell involved only portions of the full procedure given in Appendix C. The laboratory consisted of an exploratory activity directed at familiarization with the connector and backshell, primarily Steps 1 and 7, and occasionally Steps 6 and 8. Teams of two to four students assembled and disassembled the connector until they were satisfied with their understanding of this portion of the procedure (there were 7 local teams and 6 remote teams). The laboratory was conducted in all but the last class studied due to connector breakage in earlier classes (this final traditional class only viewed the instructor demonstration).

The analysis of student performance for this laboratory is largely descriptive because few events were recorded by observers as students familiarized themselves with the connector. Broad descriptive categories of these observations were developed for a total of only 23 events for both groups (1.5 average events per team for 7 local teams and 2.0 events for 6 remote teams). For both groups combined, 8.7% of the events were errors that were critical to the work product, 34.8% were out-of-order errors (failing to put parts on at the right point), and 13% were other miscellaneous errors. The remainder of the events (43.5%) were classified as struggling with the connector during assembly, encountering a problem, or seeking help to resolve a problem. The most serious error critical to the work product involved breaking the strain relief spacing shaft, such as by applying to much lateral force during assembly/disassembly. A spacing shaft was broken once in the local group and once in the remote group (one was also broken in the traditional group not included in this analysis). Combining all three error categories, there was an average of 1.14 errors per team for the local and 0.83 errors per team for the remote group. For the category on struggling, there were 0.43 events for the local and 1.16 for the remote. These descriptive statistics do not suggest any notable differences among the two treatment groups in terms of performance during this laboratory.

Help During Group Activity Laboratories

Help and assistance were recorded in two laboratories where students worked as teams. These were the Hughes connector and test equipment laboratories. Because the laboratories were by

definition group activities, instances of students helping one another were difficult to judge as students worked together on a common task and so this form of help was not included.

Help and assistance for students during the Hughes laboratory varied by site in terms of who initiated the assistance. The average events per team of student initiated help requests directed toward the instructor or facilitator was similar between the groups (3.1 local; 3.0 remote). However, assistance initiated by the instructor or facilitator toward students was much less likely for remote than local students (2.9 local and 1.0 remote average events per team).

Help and assistance were also recorded during the laboratory where students practiced using the test equipment on the fiber optic systems in preparation for their performance test. There were eight total teams for each of the local and remote sites. For help and assistance initiated by students toward the instructor or facilitator, local students averaged slightly more instances per team (7.5) than did remote students (5.6). However, help and assistance initiated by the instructor or facilitator toward students was much more frequent for the local site (6.75) than for the remote site (2.6).

Taken together, both of these team activity laboratories showed a similar pattern and differed in one respect from the laboratories where students worked as individuals (i.e., ST, rotary, and performance test laboratories). Local or remote students initiated help several times more often than the instructor or facilitator initiated help during laboratories where students worked individually. This was also true at the remote site for group activity laboratories, but at the local site there was a similar level of student initiated and instructor initiated help. That is, the instructor tended to join in with the local site student teams and offer more assistance during the group activity laboratories. This was not true for the distant remote site students who may have been perceived as being internally occupied with their own activities.

Time to Complete Laboratories

There was a tendency for the remote site student laboratories to take longer than the local site laboratories. The longest time taken by students for a laboratory was averaged for the four class convenings. The average longest time taken was greater for remote than local classrooms by 10 minutes for the ST connector laboratory, 20 minutes for the rotary laboratory, 4 minutes for the Hughes connector laboratory, and 11 minutes longer for the test equipment laboratory. The average time per student taken for the first student performance test differed by less than a minute between local and remote students. However, remote students averaged 8.9 minutes longer than local students in completing the second performance test. These differences are not large and the simplest explanation for the longer time taken by remote students would be the extra time taken for communications with the local site instructor. The absence of within room help from an instructor might also contribute to this finding. In any case, slightly more time for remote than local site laboratories might be expected in other similar courses conducted in the future.

Interaction Tally

Instructor and student interaction over the VTT network is shown in Figure 12. The figure shows two y-axis scales (interactions per hour and interactions per student per hour), and both

represent the level of interaction for an average class (per class basis).[7] The results shown here combine all instructor questions (directed to a site, a student, or open to anyone) and all student questions (individual questions and extended exchanges). Appendix E gives separate results for these subcategories for both of the rate measures. The figure shows instructor and student questions for three types of course activities: lectures on the first day of class, the combination of four instructor demonstrations, and a combination of the corresponding four student laboratories following those demonstrations. The demonstrations or corresponding student laboratories covered the topics on the three connectors (ST, rotary splice, and Hughes) and the test equipment (practice using the OTDR and OLTS on a fiber optic system).

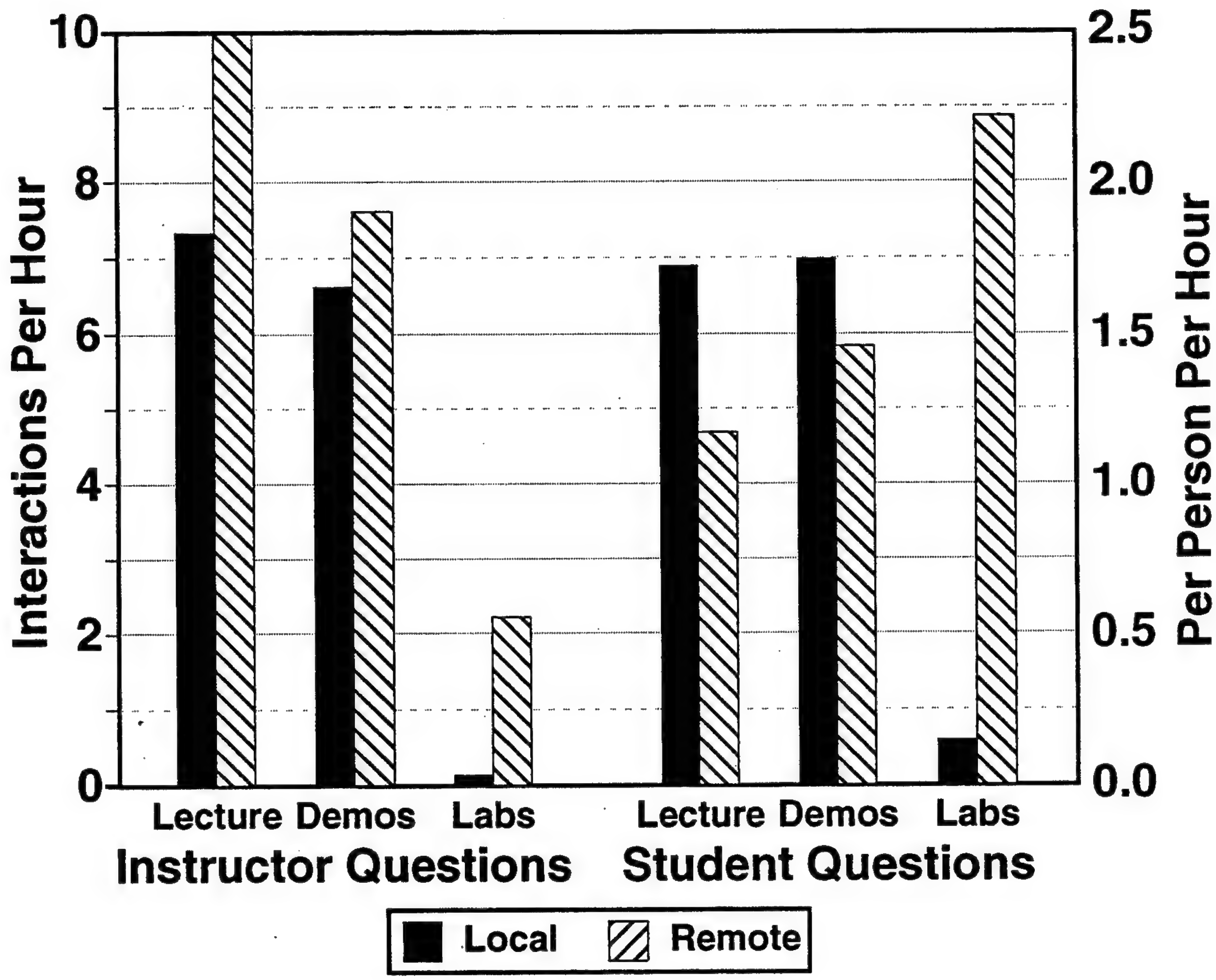

Figure 12. VTT interaction tally results for instructor and student initiated questions during three course activities.

[7]It is possible to display exactly the same pattern of results for these two measures with the present data only because there are equal numbers of students and classes per treatment group so that the measures only differ by a constant.

For instructor questions that were answered, there is a small but consistent trend for a higher level of interaction for the remote site. The slight advantage for remote students is largely due to the subcategory of instructor questions that identified a site to respond. The level of instructor questions is low during laboratories compared to lectures and demonstrations.

The level of student questions is only slightly below the level of instructor questions during lectures and demonstrations. There is a very slight tendency for local students to ask more questions during lectures and demonstrations, a reversal of the pattern shown for instructor questions. During the individual work performed in laboratories, remote students continue to use the network to ask questions of the instructor, whereas local students cease to use the network. Remote student questions are also about a third higher during laboratories than during the demonstrations and lectures. Instructor questions are not frequent and remote students ask questions during laboratories about 8.8 times an hour, or about 2.2 per student.

Statistical significance testing for this data is made difficult because there are only four classes to use as observations. Using interaction per hour ratios computed for each of the four classes as data, the nonparametric Mann-Whitney U-test revealed only two significant group differences for the data shown in the figure ($p < .02$). It is obvious from Figure 12 that local and remote groups differed significantly in their level of interaction during laboratories for both instructor and student questions.

Taken together, the interaction tally results indicated little disadvantage for remote-site students in terms of the level of instructor-student interaction. Both sites use the network during lectures and demonstrations when participating as a combined class. When working individually or in small groups during laboratories, the network was used primarily by remote students to ask questions of the instructor. In parallel with these interaction tally results, it was previously noted that help and assistance during laboratories was also more frequently initiated by remote students than by the instructor or facilitator.

Written Examination

The written examination given on the last day of the course consisted of 34 multiple-choice items covering information from the trainee guide and lectures. Students passed the test if they scored at least 75% correct, or took an alternative form of the test if they fell below this criterion. One traditional student and three remote site students fell below 75% on their first test. These students were retested immediately with no intervening instruction and all passed the second, alternate-form test.

The percentage correct on the first examination was highest for the traditional group (85.7%), followed closely by the local group (84.7%), and was lowest for the remote group (80.1%). Thus, traditional scores were 1.0% higher than local scores and 5.6% higher than remote scores, while local scores were 4.6% higher than remote scores. The difference among treatment groups was not significant by a one-way ANOVA, $F(2,47) = 3.06, p > .05$.

An alternative analysis that could be substituted for that just given would be to use a student's best score for those four individuals who took an immediate retest with the alternative test form. Using this method, the percentages correct for the groups were 86.1% traditional, 84.7% local, and

82.9% remote.[8] Thus, differences between the remote group and the other groups were attenuated, with traditional scores being 1.4% higher than local scores and 3.2% higher than remote scores, and local scores being 1.8% higher than remote scores. This alternative analysis also showed no significant between group differences, $F(2,47) = 1.34, p > .05$.

These results suggest only a small and nonsignificant decrement for remote site students relative to the other groups. Previous research indicates that there is typically little impairment for remote students on lecture-based material (Wetzel, et al., 1994). As noted later in discussing student questionnaire comments, there were routinely disputes on the content or wording of several test items, indicating a need for a revision of the test.

Student Questionnaire

Student evaluations and perceptions of the training and of VTT were measured with a post-course questionnaire (Appendix F), which contained statements to be rated, multiple-choice questions, and open-ended questions. A subset of items that applied only to students in VTT classrooms was not included on the questionnaire given to traditional students (i.e., Items 20-23, 37, and 42-46).

Not all of the questionnaire results will be discussed because there were in general only small and nonsignificant differences between the treatment groups. Therefore, a detailed presentation of the results for most of the questionnaire has been placed in tables and figures found in Appendix H.

Rating Items

Students rated 46 statements on a 5-point scale with a midpoint of 3 using the following scale values and labels: (1) strongly disagree, (2) disagree, (3) neither agree/disagree, (4) agree, and (5) strongly agree (Item 34 used a different scale as described in Appendices F and H). A one-way analysis of variance (ANOVA) was computed for each item to determine the statistical significance of rating differences among traditional, VTT local, and VTT remote classrooms.[9]

Only three of the 46 rating items yielded a significant difference between the treatment groups (Items 11, 18, and 20). Most students gave positive ratings to the dimension being measured because the average ratings for the positively phrased items were well above the midpoint of the rating scale at a little above four on the five point scale. A typical pattern observed in previous VTT research with similar scales has been that the highest ratings are given by traditional students, closely followed by VTT local students, and the lowest ratings are given by VTT remote students (Simpson, et al., 1990, 1991a, 1991b, 1992, 1993, 1995; Wetzel, 1995; Wetzel, et al., 1995). The pattern observed with the present questionnaire data only weakly follows this pattern.

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[8]Standard deviations for the traditional, local, and remote groups were 5.86, 6.09, and 5.12 for the best examination scores and were 6.55, 6.09, and 8.14 for all first examination scores described in the previous paragraph.

[9]The degrees of freedom and *F* ratio results for these main effect tests are shown in the ANOVA T-L-R columns of Table H-2 in Appendix H. If a main effect was significant, Tukey HSD tests were also computed to examine which of the pairwise mean differences contributed significantly to the effect. Asterisks in the last three HSD columns of Table H-2 indicate significant differences for the pairwise combinations among traditional (T), VTT local (L), and VTT remote (R) conditions (i.e., T-L, T-R, L-R). Most of the mean differences in Table H-2 are small and few are statistically significant at the .05 level as a consequence of the relatively small sample sizes.

Student Prior Experience. Three rating items asked students about their prior experience with fiber optics. Average ratings indicated that the students generally had a low degree of prior experience (Table H-1 of Appendix H). Ratings for prior basic knowledge of concepts and facts (Item 1) were somewhat higher than for skill in performing cable repair (Item 2) or troubleshooting tasks (Item 3). There were no significant differences among the treatment groups on each of these three ratings items, although local students tended to rate prior knowledge of concepts and facts in fiber optics higher than the other groups.

Significant Rating Items. Only three of the rating items yielded a significant difference between groups. There was an overall significant difference ($p < .05$) among groups on Item11, which was largely due to the local group rating the lecture and theory portion of the course lower than the other two groups. On Item 20, remote-site students gave significantly ($p < .05$) higher ratings for the connector repair videotapes than did local students.

There was a significant difference ($p < .01$) on Item 18 where the readability of the instructional graphics shown on slides or transparencies were rated significantly higher by the traditional group than either the local or remote students. This finding may partially result from the reduced resolution provided by video for materials that had originally been designed for higher resolution displays. Additionally, difficulties were experienced during the first VTT class in using overhead transparencies on the video document camera because of the selection of colors used in the transparencies. During subsequent VTT classes, an alternative version of the materials on 35mm slides was presented with better results by using the video-based 35mm slide projector.

The rating scales and many of the questionnaire items used here were very similar to those used in previous VTT research (Simpson, et al., 1990, 1991a, 1991b, 1992, 1993, 1995; Wetzel, 1995; Wetzel, et al., 1995). Prior experience with these instruments would suggest that rating items with group differences of about a half a rating unit would generally have yielded significant results if the sample sizes were two or three times larger. Differences of at least a half a rating unit between VTT local and remote students shown in Table H-2 of Appendix H are rarely this large. In all cases where a difference this large was obtained, remote students actually gave higher ratings than local students (Items 4 through 46). These items were concerned with the adequacy of lectures (Item 11), the value of connector videotapes (Items 20 and 37), usefulness of the computer based instruction (Item 23), and the ability to perform the connector laboratories (Item 38). Thus, for the two VTT groups receiving exactly the same course of instruction, there is no detrimental trend for remote site students using a loosened criterion to anticipate possible group differences with a larger sample size.

Course Activities. A primary concern of the present evaluation was whether different portions of a hands-on laboratory course would present difficulties when delivered by VTT. Figure 13 shows the results for a block of questionnaire items where students were asked to rate the extent to which different portions of the course could be accomplished effectively (Items 35 through 41). There are no significant differences between groups on any of the items shown in the figure and the ratings by remote students are often slightly higher than those of the local students. Additionally, it is apparent that there is little overall differentiation between the types of activities. Combining all three groups, the largest difference among the questions is one half of a rating unit, and the two lowest rated items concern the students' own work in the connector (3.84) and troubleshooting (3.87) laboratories. Similar results were obtained for other rating items in the questionnaire that addressed the same topics covered in this block of items (e.g., items 6, 11-16, and 29).

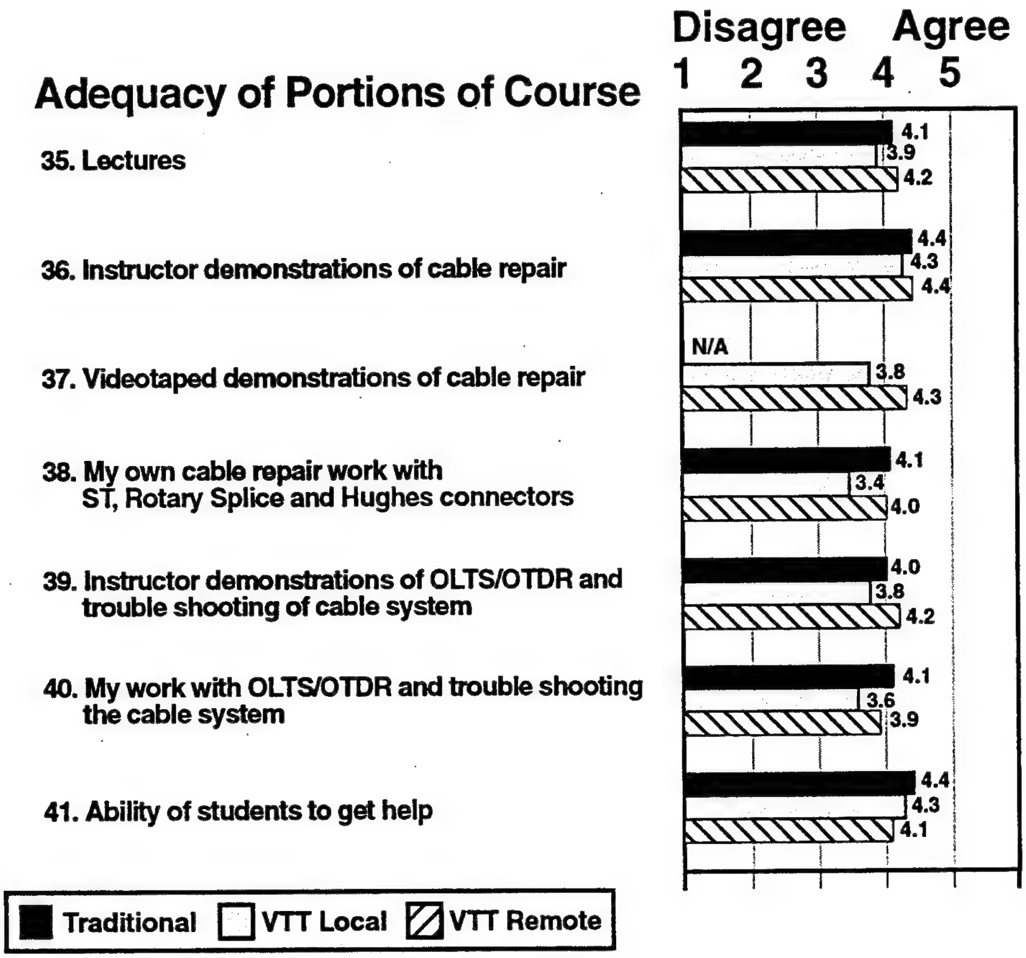

Figure 13. Student questionnaire ratings for course activities.

Technologies. Several questionnaire items addressed the technologies implemented only during VTT classes (Items 20, 22, 23, 37, and 46). These items were rated on the positive end of the scale, with the video microscope rated highest, followed by the videotapes, the video switching system showing individual remote students, and then the computer-based instruction. Ratings on the usefulness of the video microscope camera setup (Item 22) were among the highest ratings obtained over all questionnaire items. Both local and remote students gave an average rating of 4.8 on the five point scale, and no contrast was possible with traditional students since the device was not used in those classes. Use of the device would appear to be a useful addition to the course based on casual observations. Displays of student connector work on the screen appeared to be valuable in allowing all students to benefit from seeing a shared view of examples of good and bad work from other students. Normally, the connector ends are inspected one student at a time through an optic viewer and students must verbally describe to one another the relevant features of what is being seen.

Computer-based Instruction. VTT students were asked to rate the usefulness of the computer-based troubleshooting problems in Item 23. Following this item, they were also asked to write how many of the eight computer-based problem-solving problems had been attempted and how long they had spent on all problems. Student use of the computer program was encouraged by the instructor, but was optional in the sense that the program was used at the students' discretion at various points during the week when time permitted.

The computer-based instruction was rated one half of a rating unit higher by VTT remote students (3.8) than by VTT local students (3.3). However, this difference was not significant by a one-way ANOVA, $F(1,30) = 2.51, p > .05$. The mean number of computer problems attempted was 4.9 for local students and was 4.3 for remote students. This difference was not significant by a one-way ANOVA, $F(1,30) = 0.48$, $p > .05$. The mean number of minutes spent using the computer-based instruction was estimated to have been 46.7 minutes by local students and 60.3 minutes by remote students. This difference was not significant by a one-way ANOVA, $F(1,30) = 1.04$, $p > .05$.

For all students combined, higher ratings on the usefulness of the software (Item 23) were weakly related to a greater amount of time spent using the computer program (Pearson correlation, $r = 0.281$). A greater amount of time using the program was also weakly related to a higher percent of correct fault causes listed by students on the performance test ($r = 0.205$ for test 1 and $r = 0.22$ for test 2). However, none of these correlations were strong enough to be significant ($p > .05$).

Multiple Choice Items

Items 47-50 were given in a multiple choice format to assess student opportunities to interact with the instructor, assistance received, and preferences for an instructional method. Percentages of response to each choice were calculated within each group (see Appendix H), and Chi Square tests were used to compare the response distributions of the treatment groups.

Opportunities to Interact and Assistance. Question 49 asked "How did the VTT method of instruction affect your opportunities to interact with the instructor?" and presented three response alternatives. Most students indicated that there was "no effect on opportunities," and remote students (75%) chose this alternative only slightly less frequently than local students (87.5%). A minority of students said there were "more opportunities" (12.5% local; 12.5% remote). Only two students (12.5%) indicated that there were "fewer opportunities," and both were in the remote-site group. A Chi Square test showed that the distribution of responses among groups was not significantly different ($\chi^2(2) = 2.15, p > .05$).

Question 47 asked "Who most frequently provided assistance to you" and offered choices in terms of "Instructor," "Facilitator," "Other students," and "Other (please explain)." Most students indicated that the instructor was the most frequent source of assistance, and the percent of remote students (81.3%) was slightly less than that of local students (93.8%). One student in each group (6.3%) chose "other" and cited a combination of the other response categories. Only two students (12.5%) cited "other students" as the most frequent source of assistance, and both were in the remote site group. The distribution of responses among groups was not significantly different ($\chi^2(2) = 2.14, p > .05$). Responses to this item are similar to that found with rating Item 26 in that remote students showed only a slightly greater tendency to agree that "students aided one another

in performing tasks." By contrast, student to student help and assistance recorded by observers during the previously discussed connector laboratories was somewhat more pronounced for remote students than other students.

Previous work with a Celestial Navigation course showed slightly stronger trends for remote students to cite other students as a source of assistance, as well as to report a little less opportunity to interact with the instructor (Wetzel, 1995). The present questionnaire findings show a similar, but much weaker trend for remote students, which may be due in part to the small class size in the Fiber Optic course.

Preference for Instructional Method. Figure 14 shows the results for question 48, which asked "Which method of instruction would you prefer for this course?" The responses offered were: video tele-training (VTT), traditional method (non-VTT), and either method. Traditional students were provided a short description of VTT instruction with this question. A Chi Square test showed that the distribution of responses to these categories differed significantly among the treatment groups ($\chi^2(4) = 10.9, p < .05$).

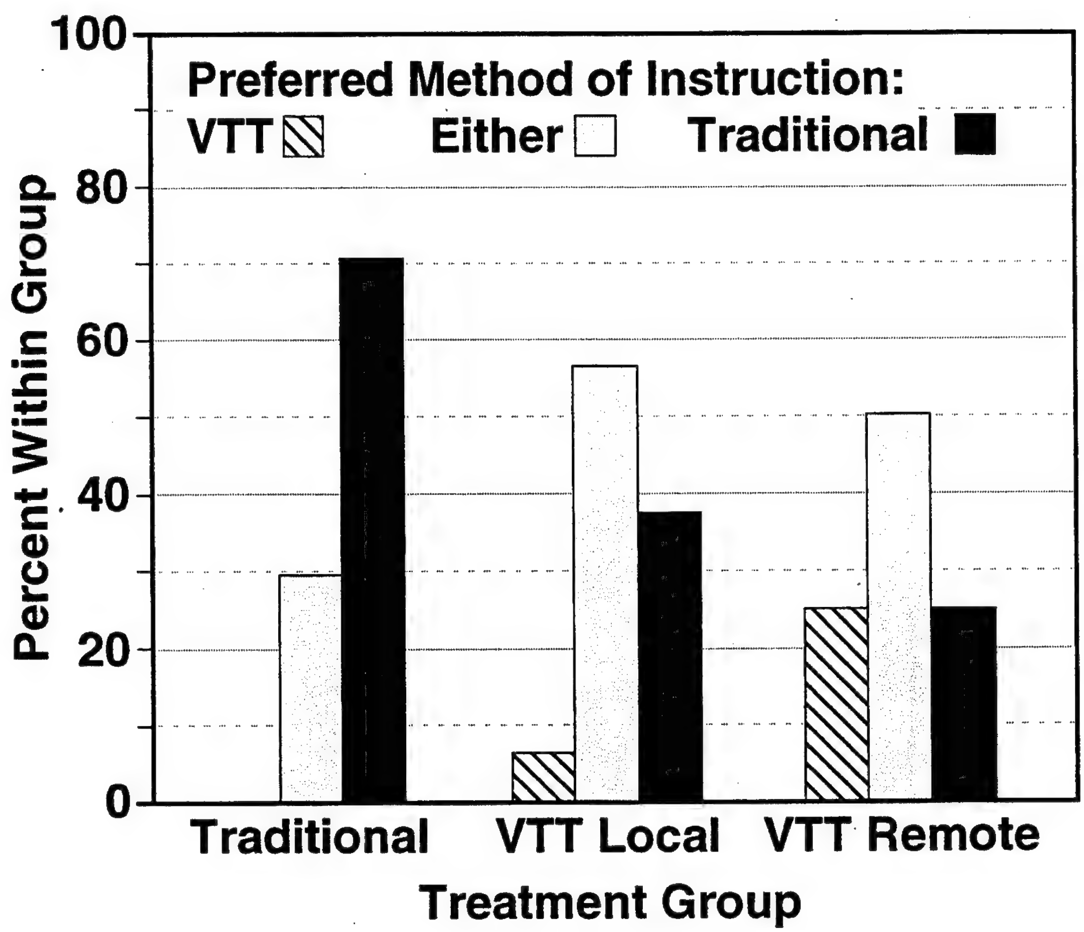

Figure 14. Student preference for an instructional method.

Traditional students were strongly in favor of the traditional form of instruction (70.6%), followed by either method (29.4%), and none chose the VTT method of instruction. By contrast, the preference for about half of the VTT local students was for either method (56.3%), followed by the traditional (37.5%) and then the VTT (6.3%) methods of instruction. VTT remote students were more divided in their preferences, with half choosing "either" method (50%), a quarter choosing traditional instruction (25%), and another quarter choosing VTT instruction (25%). Compared to traditional students, both VTT groups were more likely to accept "either" method or the VTT method of instruction. The slightly more favorable response by VTT remote students is notable because these students had experienced the full impact of the instructional method. Thus, student acceptance of VTT increases with greater direct experience with the impact of the VTT method when the group responses are ordered from traditional to VTT local to VTT remote. A similar pattern was found on this question in a Celestial Navigation course (Wetzel, 1995). The results also support the generalization from instructional television research that students may initially have negative perceptions, but these lessen with experience with the medium and become neutral or even positive (cf. Wetzel, et al., 1993, 1994).

Question 50 asked students to respond "Yes" or "No" to the question "If you had a choice, would you take another VTT course?" One local student did not answer, and the remaining 31 students in both groups all chose "yes." Thus, 100% of those who responded indicated that they would take another VTT course (including the missing response, group "yes" responses were 93.7% local, and 100% remote). Chi Square cannot be calculated because the choices were unanimous. Students were also asked to explain their yes or no answer in the second part of question 50. One student in each group (6%) did not provide a comment, and there were no exclusively negative comments. One quarter of the students offered mixed positive-negative comments that indicated acceptance of VTT combined with a qualification, such as that hands-on laboratories would be difficult to conduct with VTT (31% local; 19% remote). The majority of students (69% overall) provided positive comments indicating acceptance of VTT or a perception that there was no difference between VTT and traditional instruction (63% local; 75% remote). Thus, the most frequent comment by those who responded was positive and the distribution of responses among the two treatment groups did not differ significantly ($\chi^2(1) = 0.68, p > .05$).

Open-ended Questions

Questions 51, 52, and 53 asked students what they like most about the course, what they liked least, and to provide any suggestions to improve the course, respectively. The written responses to each open-ended question were clustered into several categories and percentages within each treatment group were calculated. The results will be briefly discussed here because the responses to these questions generally reflected aspects of the course itself and did not reveal substantial differences among the treatment groups (summary tables are given in Appendix H).

Comparing the three questions combined over treatment groups, students were more likely to respond to the question on what they liked most about the course (100%) than they were on what was liked least (72%) or to suggest improvements (88%). The only difference in overall response rates between groups was that both VTT local and remote students were more likely to respond with a "liked least" comment compared to traditional students.

All students provided at least one comment on what they liked most about the course (Item 51). For all groups combined, 82% of the comments fell in three categories having to do with the fiber optic subject matter being a valuable skill relevant to the student's job. These categories pertained to the value of learning a new technology (26%), the connector laboratories (28%), and troubleshooting skills (28%). Response rates were slightly lower in these categories for local and remote students because they also provided positive comments on VTT that were not part of the experience of the traditional students. Notably, positive comments on VTT instruction, technology, interaction, or using the VTT system were over twice as great for VTT remote students (39%) as they were for VTT local students (16%).

Student comments on what was liked least about the course (Item 52) most frequently cited three categories pertaining to the course itself (43% overall). These were disputes over the content of some test items (15% overall), that the student guide contained different test equipment than used in the course (14% overall), and the lack of connector supplies in laboratories, particularly the Hughes connector (14% overall). Negative comments on VTT were infrequent and pertained to interaction and getting help more often for remote than local students (4% local; 12% remote). A related category on instructional presentations (seeing slides and visuals, or the clarity of lecture topics) was also higher for remote (18%) than local (9%) students.

Student comments suggesting improvements for the course (Item 53) fell into diverse categories, several of which echoed comments on what was liked least about the course. Overall, about 50% of the suggestions referred to a previously noted need for laboratory connector materials (20%), increasing laboratory time or a greater variety of fiber optic systems (20%), and more troubleshooting variations and attempts (11%). VTT remote students were again more likely to make suggestions about increased interaction (4% local; 18% remote), or aspects of the presentation such as the clarity of visuals (4% local; 18% remote).

Discussion

The experimental delivery of the Fiber Optic Cable Repair course served two related purposes. One goal was to determine the feasibility of offering this course by VTT. The research indicates that it would be feasible to use this method of delivery, given several support and cost considerations discussed below. The other goal was to attempt a representative hands-on laboratory course to provide lessons learned for other similar courses that might be considered for VTT delivery. The different types of laboratory activities in this course provided a range of challenges to the VTT medium that were beneficial toward that end.

The approach to evaluating the feasibility of delivering this course by VTT involved a simulation of the local and remote sites and used a combination of course conversion techniques. Although the remote site was not truly at a distant location, every effort was made to create realistic treatment conditions. The success in delivering the simulated course suggests that an actual implementation could not be substantially less successful. The modified course given to VTT students combined several elements that were not studied as separate experimental variables. The combination of interventions common to VTT local and remote students was not used for traditional students in order provide a representation of the pre-VTT course configuration. The

VTT local and remote treatment groups provided the most important comparison because the groups shared the interventions and exactly the same instructor presentations.

The discussion below includes a brief review of the empirical findings for the data collected, a number of observations by the researchers that resulted from conducting the study, and a consideration of course support and cost issues.

Summary of Empirical Findings

There were no significant differences in student performance indicating any impairment for remote site students as a consequence of delivering the course by VTT. Procedural errors during the ST and rotary splice connector laboratories were no higher for remote students compared with either local or traditional students. There was a small increase in nonserious technique and cleaning errors for the traditional group that were hypothesized to result from a combination of factors: VTT students viewed both a videotaped and live demonstration of the procedure while traditional students only viewed it live, and errors were assessed with a check list that emphasized a few techniques shown in the videotape. There were about 20% fewer errors during the second laboratory for all groups combined, suggesting some benefit from the experience with the first laboratory. Observer ratings of the student work product and objective light loss readings for the connectors did not vary systematically among groups. Observer safety ratings did not differ significantly among the treatment groups. About 6-7% of all students received the lowest rating on wearing eye glasses and controlling fiber fragments.

Troubleshooting test performance on faulted fiber optic systems also revealed no significant differences between the treatment groups. The groups did not differ in their success in finding a fault, in suggesting possible fault causes, or in identifying corrective actions. There was some improvement from the first to second test system in identifying corrective actions and in the amount to time required to complete the test. Students required less time to solve the fault on the second test system attempted; however, this decline was less pronounced for remote students.

Student performance on the final multiple-choice examination was slightly lower for remote students than those in the other two groups. There is typically little decrement for remote students on lecture-based material (Wetzel, et al., 1994).

There was a slight trend toward a need for greater help and assistance for remote site students during the ST and rotary laboratories and also a slight trend for remote students to aid one another more. Help declined from the first to second performance test, and the decline for remote students tended to be a little less than for the other groups. About half of the helps on the performance test concerned troubleshooting logic, a quarter concerned the test equipment, and another quarter pertained to entries to be made on the test form.

The tally of interactions across the network indicated little disadvantage for remote-site students in the level of instructor-student interaction. Interactions for local and remote sites were generally at similar levels during lectures and demonstrations when students participated as a combined class. During these activities, instructor initiated questions slightly favored remote students, while student initiated questions were only slightly higher for local than remote students.

During laboratories when students worked individually or in small groups, the network was used primarily by remote students to ask questions of the instructor.

Student questionnaire responses revealed few differences among the treatment groups. Only three of 46 rating items showed significant groups differences, in part due to the small sample sizes. Ratings on different course activities did not reveal any significant differences among groups in perceptions that some activities were more difficult to conduct than others. Most students indicated that they would take another VTT course. When asked for their preferences for a method of instruction for this course, only 37.5% of local and 25% of remote VTT students would choose traditional instruction as opposed to VTT or either method of instruction. VTT students who experience the impact of VTT were more accepting of the VTT method of instruction than were traditional students. Student responses on open-ended questions tended to reflect aspects of the course itself rather than concerns with VTT.

Taken together, there was little difference between the treatment groups on a variety of measures and there was no indication that remote site students suffered a significant disadvantage in their performance. However, the need for help and assistance tended to be a little higher for remote students. The amount of time required to complete the various laboratories periods in the course was also generally longer for remote than local students.

Observations from Conducting the Course

Several observations by the researchers evaluating this course are relevant to the requirements and techniques for conducting this and other hands-on laboratory courses by VTT. The most notable lessons learned concern the preparation of students for laboratories, the various roles to be assumed by a facilitator, the potential for increased demand on CESN staff, and the aid provided by technology. Conducting the research also revealed that the preparation efforts for delivering this kind of course can be extensive.

Instructional Issues

When remote students perform laboratory activities at a distance from the instructor they must use the VTT system to communicate with the instructor, rely on resources at their site, or rely on prior instruction to work more independently. In traditional laboratories, students cluster around the table where the instructor delivers a demonstration. The instructor circulates among students when they perform their laboratory work, looks over their shoulders to observe progress, and delivers instruction as needed in an adaptive fashion. These interactive tutorials amplify details, clarify concepts, or provide the student with corrective guidance. This form of instruction may appear unplanned when students seek help, are observed to need help, and when conveyed through casual conversations.

The learning environment in traditional laboratories may need to be conveyed in different ways to provide the same information to remote students who are not physically co-located with the instructor. One way is through concerted efforts to use the VTT system to communicate in familiar ways and to use video technology to allow better views of the activities between sites. Another method is to better prepare students prior to the laboratory. Information conveyed during interactive exchanges in traditional laboratories can be developed into an explicit instructional

segment prior to the laboratory to better prepare students for performing more work on their own. The idea that students can do work on their own would seem to highlight the weakness of using the VTT system. Although designed to benefit VTT remote students, it may also be seen as an extension of good instructional practice that would be applicable for non-VTT classes. There were three instances in the approach to this course that illustrate an attempt to better prepare students for conducting their own laboratory work: the use of videotapes prior to connector laboratories, the computer-based instruction on trouble-shooting, and enhanced lectures prior to the test equipment laboratories.

The connector laboratories were successfully delivered as a consequence of the greater preparation devoted to this portion of the course. VTT students were given the demonstrations twice, while traditional students only saw the live demonstration. The live instructor demonstrations for VTT classes were found to be effective in part because the material showed well under the document camera and in part because the instructors practiced delivering the demonstrations to achieve a high level of quality. Tapes can be used as an alternative to or a complement to live demonstrations in other courses to standardize the content and quality of instruction. As noted, there was a hint that the tapes standardized the instruction in that some minor technique errors were more frequent for traditional students who only saw the live demonstration, a trend that was only apparent after the data were analyzed.

Several observations on the difficulties encountered by students during the connector tasks are well known to fiber optic instructors. The listing of errors given in Appendix G may be useful in developing additional tips for students on common errors that are made on these tasks. Cleaving was a common problem, such as when a glass fiber was broken or shattered down into the connector. Although visual aspects of this task would appear to be important because the glass fiber is difficult to see, the tactile aspect of this task is significant. The instructor must verbally emphasize how cleaving "feels" and how to detach the fiber by pulling rather than by bending. Student performance on this task would be enhanced if the course allowed more cleaving practice using some method that avoided expending a connector.[10] Another common group of problems related to polishing, cleaning, and deciding when the polish was completed, particularly during the rotary splice laboratory. The instructor's guidance is important during this phase of the task and students often seek assistance in judging the adequacy of the connector. Both local and remote students were able to obtain this guidance by using the video microscope. Showing the class examples of faulty connectors from prior laboratories would be recommended as an alternative to the lower fidelity drawings provided in the trainee guide.

The test equipment and troubleshooting laboratories were somewhat more challenging to deliver by VTT than were the connector laboratories. The connector laboratories had been better prepared prior to conducting the course and involved a series of steps that were relatively more concrete in nature. Instruction in the test equipment and troubleshooting laboratories underwent refinement during the research study as more experience was gained in delivering these kinds of activities by VTT. Activities that were difficult to accomplish over the VTT network typically involved interactive back and forth exchanges in front the equipment. For example, successive

[10]A method would be needed to hold a fiber inserted in a connector that had not been epoxied so that the connector could be reused for several practice attempts at cleaving, such as by pushing a small amount of fiber through a connector and using piano wire for cleaning out connector channel obstructions.

adjustments on the OTDR test set may be required to display the correct scale so connector junctions can be viewed on the screen. Interpreting the meaning of OTDR displays showing connector locations along the fiber path could also involve interactive explanations involving pointing at the screen. Some students also needed guidance in applying somewhat different troubleshooting logic than in electronic systems because test points must be considered in terms of the direction of transmission. It was not uncommon for additional learning to take place in instructor-student exchanges during the performance test, where assistance given to students primarily concerns troubleshooting logic, followed by test equipment operation. The instructor's inability to circulate among remote-site students to provide this assistance in the normal fashion focused attention on the need to better prepare students for these laboratories (this was also the original impetus for developing the computer-based instruction). It became apparent during the early class convenings that the need for help in several areas could be lessened by explicitly presenting important aspects of the assistance normally given during the laboratories. Lecture material was enhanced to address observed student problems and this material was then presented prior to conducting the test equipment and troubleshooting laboratories. Following this enhancement, instructors judged that difficulties encountered by VTT students were lessened during later classes.[11]

The two-way audio and video system allowed the instructor to monitor remote students, who in turn used the system to contact the instructor when they needed assistance. Instances of help and assistance during laboratories were primarily initiated by students (76% remote and 67% local). Local students always received assistance from the instructor, whereas remote students received assistance from the instructor and also depended on resources within their own remote room. The proximity of the facilitator to remote students was reflected in the higher proportion of help associated with the facilitator and it also appears to have affected the tendency for remote students to help one another more than did local students. Help requests initiated by remote students during the five laboratories were directed toward the facilitator (55%) slightly more often than toward the instructor (45%). The less frequent instances of assistance directed toward students were also more frequently initiated by the facilitator (72%) than the instructor (29%). Much of the facilitator help concerned logistics issues outside of the subject-matter expertise of the instructor, such as assistance in operating the VTT system and cameras, or in showing connectors over the system. However, another important role played by the facilitator is behavioral, when acting in behalf of students and when serving as an agent of the instructor. In particular, the facilitator observes problems encountered by students or receives student questions within the room and then "redirects" these to the instructor for resolution. The present study also suggests that remote site laboratories should be expected to take a little longer. This may result from logistical delays in establishing communications with the instructor or possibly from remote students not having the benefit of an instructor who is immediately available within the room to provide assistance and tutoring.

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[11]Remote student help and performance test times were highest during the first class convening. Combining local and remote groups, the last two class convenings were below the first two convening by 5.25 helps per team in the test equipment laboratory, 1.68 helps per person on the performance test, and the time to complete the performance test was 11.5 minutes less.

Supporting Technologies

A combination of instructional technologies and equipment were used in the approach to delivering the course by VTT. The use of these technologies to support the course illustrate several themes that are applicable to delivering other VTT courses: (1) increase the visibility of activities among sites, (2) use technologies to assist students during laboratories or to better prepare students for laboratories, and (3) reduce demands on the instructor with the aid of automated technologies, such as those that avoid the need for a camera operator. These themes were illustrated in sometimes overlapping ways in the present study by the use of the computer-based instruction, videotapes, video microscope, portable cameras, demonstration camera with presets, and the microphone-based switching system.

Several questionnaire rating items addressed the technologies used in the course without experimentally comparing them. For example, by alternately presenting and withholding a picture-and-picture display of an instructor and his graphics in a course where an instructor was normally off-screen, it was found that remote students favored the combined display (Wetzel, 1995). VTT students always received the technologies in the present study, and there was only a slight trend for remote students to rate some technologies slightly higher than local students. Remote students gave significantly higher ratings to the connector repair videotapes that were developed to offset any difficulties with delivering live demonstrations. The computer-based instruction used to prepare students for trouble-shooting was also rated higher by remote than local students, but the difference was not significant even though it was of a similar magnitude to the ratings for the videotapes. Student performance on the performance test was not clearly tied to having used the computer-based instruction in this study. The video switching system and the video microscope were each given the same average rating by the two groups. Student ratings for the microscope were one of the highest ratings obtained on the questionnaire. The video microscope allowed fiber optic cable ends to be inspected remotely and was clearly a benefit in allowing all students to share a view of good and bad examples of connector work. The public view of the connectors circumvented the difficulty of verbally describing what was being seen in the traditional viewing scope that only one person could view at a time.

Several camera configurations were used to explore their potential for aiding the instructor or increasing the visibility of activities at the remote site. The small portable camera using preset pan/tilt/zoom positions worked very well during instructor demonstrations of test equipment and eliminated the need for a supporting camera person. The document camera found in all CESN VTT classrooms worked well for the demonstrations of connector repair because it allowed extreme close-ups of the small items that were shown. A six position manual video switch attached to the side of the instructor podium was beneficial in expanding the number of video sources available to the instructor at the podium. The flexible gooseneck camera was found useful by instructors during demonstrations when many tools and parts were arrayed beyond the view of the document camera. This camera has subsequently been used in other classes for demonstrations showing large items that will not fit under the standard document camera. When outfitted with a long extension cord, this camera was also used occasionally at the remote site to show details at a student workstation normally too distant for other cameras to show. Each of these video configurations would be of value at other CESN sites. However, their value depends on either training instructors in their use or the support of a facilitator.

The video-switching system operated by student push-to-talk microphones was useful in showing a better view of individual students at their workstations. The system used in this study showed the width of a table and provided a clear view of large items and the student, but small items had to be shown with the flexible gooseneck camera or taken to the document camera at the podium. CESN classrooms are typically configured to show a wide view of the classroom. A narrower view is occasionally used to show some students in good detail by manually adjusting a pan/tilt/zoom camera. An automated system like the prototype developed here would be of value at remote sites. It could be configured with fewer cameras to show alternative halves of the classroom so that student faces and expressions would be more visible over the system. However, the liabilities of this configuration are its expense and the need to outfit classrooms with microphones having a second set of contacts to be used in triggering the system. Off-the-shelf technology using a single pan/tilt/zoom camera is currently available for this purpose, although the movement shown in the views with this configuration could be slightly more distracting than the immediate "cuts" between views in the system used in this study (cf. general reviews of production techniques in Wetzel, et al., 1994).

Site Support and Costs

Support and cost issues associated with offering this course by VTT should be considered in addition to the instructional feasibility of delivering the course. Delivering the present course by VTT would require somewhat greater efforts on the part of site personnel and would involve additional support logistics associated with the array of equipment and supplies required. These liabilities are not insurmountable for this course and they may not represent requirements in other laboratory courses that would have to be considered on a case by case basis.

VTT Facilitator. The remote site facilitator plays an important role in supporting VTT courses. Normally, the facilitator is present during portions of a class, is the technical expert on the operation of the VTT system, operates cameras and other equipment, prepares the classroom, distributes class materials, serves as a test proctor, and scores examinations. The hands-on laboratories in the Fiber Optic course would increase demands on the VTT facilitator and would require that the facilitator play a greater role during the delivery of the course.

A facilitator would be required to be physically present in all laboratories in this course. This presence is primarily for the purpose of serving as a safety monitor. The main safety concerns in this course are ensuring that students wear safety glasses, control fiber fragments, and are careful with the adhesives, tools, and the low power laser light source. These issues would not prevent the course from being delivered by VTT if the facilitator were present during laboratories to issue a warning to the occasional student who disregards these safety concerns. As noted previously, a facilitator for this course would also act as an agent of the instructor in monitoring problems encountered by students and in acting as an intermediary to the instructor by redirecting the need for assistance or student questions to the instructor.

Greater facilitator assistance would also be required because of the additional equipment used in this course. This would include operating the small portable cameras, and providing assistance when student work is shown to the instructor via the microscope and the document camera. During laboratories, the facilitator would also have to operate the OLTS to establish reference settings so students could test their connectors. The facilitator would also serve as a test proctor and would

have to set up or restore some troubleshooting test problems on the portable system carts during the performance test. As in other VTT courses, a list of daily course events should be provided to remote sites to ensure that materials and equipment are ready at the appropriate time.

These support functions suggest that facilitators would be required to be more knowledgeable of course content than is usually the case. A facilitator could possibly take the course as a student to become acquainted with the course procedures. Many facilitators are already from technical ratings related to electronics. However, it should be noted that recurring issues for the CESN concern how much skill facilitators should have in the content of the various VTT courses and how much time they have available when performing the facilitator role as a collateral duty.

Site Support Issues. There would be greater logistical demands on both local and remote sites to deliver the Fiber Optic course by VTT. A facilitator would be required to set up a room with course equipment and then store it away following a class. Storage space at a site would be required between class convenings. Storage required for equipment in this course was equivalent to that in a small office. There would also be a greater demand on the resources of the remote site to maintain a stock of the various consumable supplies used for the laboratories of this course.

A flexible classroom layout can accommodate a variety of courses and would enable laboratory courses to be delivered with less difficulty. Greater classroom space is the primary factor in accommodating demonstrations and laboratory equipment used in this kind of training. There is some variability in the size of current VTT classrooms, and these activities could be better accommodated if future VTT classrooms were selected to provide somewhat greater space at the front and one side of the room and for student work areas within the room (cf. Simpson, et al. 1992; Simpson, 1993; Wetzel, 1995). Other room considerations for this course involved providing power to student workstations by using low profile power cords for test equipment and the need to increase the room electrical power supply to accommodate this equipment.

VTT classrooms are used by different courses. Setting up a VTT classroom for a laboratory course can be made easier if the required training equipment is portable or can be adapted to be portable. The fiber optic cable systems used in this course were installed on roll-away carts and this method could be used for a variety of training equipment in other courses. The variety of other small items in this course also lent themselves to being taken in and out of the classroom (e.g., suitcases containing the connector repair kits). Other laboratory courses have been successfully delivered by VTT which involved less support and laboratory equipment demands. Fewer items than used in Fiber Optic course are routinely taken in and out of VTT classrooms in a Celestial Navigation course without imposing undue burden (cf. Wetzel, 1995). A computer laboratory in a Quality Assurance course has also been conducted successfully by using portable laptop computers linked to a laser printer via a wireless local area network that avoided a clutter of wiring in the VTT classroom. Simpson et al. (1992) also used portable roll-away training aids for demonstrations in a Damage Control Petty Officer course or used videotapes to replace live demonstrations.

Cost Considerations. Offering the Fiber Optic course by VTT can also be considered in terms of the costs involved. Delivering laboratory courses by VTT could involve cost issues that are not found with lecture-based courses given by VTT. For example, some laboratory courses may have a small number of students or require expensive laboratory equipment. Cost saving associated with the use of VTT are realized when student travel costs are avoided because students do not travel

and instead receive training by VTT near their duty station. The overall costs for maintaining a VTT system are offset to the extent that the VTT system is used intensely. Increased usage results from fully scheduling VTT classrooms, courses with many students, and short duration courses permitting more classroom usage. Laboratory courses with few students are therefore a concern from the perspective of offsetting VTT system costs with sufficient usage. Several cost elements can be examined to provide a general idea of the magnitude of the costs involved for the Fiber Optic course. These are the initial costs for equipment required to establish a remote site, costs of using the VTT system, and student travel costs.

Unlike lecture courses, initial setup costs for a remote site are relatively high for the laboratory equipment required for the Fiber Optic course. Initial setup costs to accommodate a full laboratory of eight students would be about $175,000 (including construction of portable system carts and a video microscope, but no other video equipment). Most of these costs reflect the expense of four OTDRs, costing about $30,000 each. For a class this size, recurring costs for consumable supplies would be about $450 per class. A remote-site laboratory with fewer students would reduce these initial and recurrent costs accordingly. These expenses to outfit a remote site would not be additional costs to those for VTT in the event that a site originally planned to be taught in the traditional manner were instead taught by VTT (i.e., additional training sites such as Pearl Harbor are projected in an existing Navy Training Plan).

A successful use of VTT would be indicated if the avoided costs for student travel exceeded the costs for using the VTT system. The analysis used to judge the success of the CESN system involves a comparison of the contract costs for maintaining the VTT system with avoided student travel costs that result because training is not available at remote sites and students must travel.[12] A similar analysis can be applied on a smaller scale to the Fiber Optic course. This comparison of VTT contract costs and avoided student travel costs is described below on a per class convening basis.

The average contract cost per room over all CESN VTT classrooms is approximately $70,000. Assuming 251 available training days per year, the per day cost of an average VTT classroom would be $278, and five days of use for this course would cost $1,390. Assuming two participating sites (local and remote classrooms), the five day class convening costs would be $2,780.

Student travel costs can be illustrated for two class sizes at several alternative sites. Four or eight students per class convening can be assumed based on the 1:4 instructor/student ratio at existing sites (one instructor with four students at Norfolk and two instructors with eight students at San Diego). The best possible cost savings scenario for this course would be where students traveled from Pearl Harbor to attend a class in San Diego (total per student costs would be $650 based on current Government rate round trip airfare of $480, $20 local travel, and $150 for six days of per diem). For comparison purposes, alternative sites involving shorter travel distances to San Diego might be considered at Seattle and San Francisco (total per student costs would be $388 and

[12]CESN cost estimates from March 1989 to September 1995 indicate a total contract cost of $5,164,456 and total avoided costs of $9,174,332 ($7,108,424 training costs and $2,065,908 conference costs). Thus, contract costs are about 56% of the estimated avoided costs, which leads to the statement that system operation starts to break even about midway through a year. Excluding the ancillary use of the system for conferences, the contract costs are about 73% of the estimated avoided training costs. The average number of students per classroom is about 10 or 11. An early cost analysis of the CESN is given in Stoloff (1991).

$246, respectively). The avoided per convening travel costs for the Pearl Harbor, Seattle, and San Francisco alternative sites would then be $2,600, $1,552, and $984 for a four student class convening; and $5,200, $3,104, and $1,968 for an eight student class convening.

These avoided student travel costs can be compared to the $2,780 cost for using the two VTT classrooms that was estimated above. The $2,600 avoided travel costs for four students from Pearl Harbor almost reach the level of the VTT classroom costs. The two other less distant sites fail to generate enough travel avoidance to exceed the VTT costs ($1,552 and $984). With eight students, both Pearl Harbor ($5,200) and Seattle ($3,104) have avoided travel costs in excess of the VTT classroom costs, but not San Francisco ($1,968). Thus, avoided travel costs are small with few students and are larger with more distant sites. Any shortfall in the number of students per convening would be detrimental to the cost avoidances that are close to the costs for using VTT. With eight students, there might also be an added load on the instructor to monitor remote students and possibly the need for an additional facilitator if the existing 1:4 instructor/student ratio were also applied to facilitators.

This analysis suggests that a small number of students in this course appears to be the greatest concern from the perspective of enhancing VTT system utilization. Beneficial system use is based on generating avoided travel costs in excess of the cost of using the VTT system. The extra effort to conduct this laboratory course by VTT combined with the small class size do not suggest much advantage for using VTT. However, other laboratory courses that accommodate more students could be cost beneficial.

Conclusions

The following conclusions summarize the important aspects of the foregoing discussion on offering this and other similar laboratory courses by VTT.

Feasibility and Delivery Approaches

It is instructionally feasible to deliver the Fiber Optic course by VTT based on the results of this experimental evaluation. Lessons learned from the research suggest the following approach for delivering this kind of laboratory course.

- Enhanced preparation of remote students prior to performing their laboratory work should be used to offset the reduced assistance available when students are at a distance from the instructor. Examples of this preparation include the use of videotapes, computer-based instruction, and moving topics taught during laboratories into lectures and demonstrations given prior to conducting laboratories.

- The VTT facilitator plays an important behavioral, technical, and logistical role in laboratory courses. The VTT facilitator would need to be present during all student laboratories in this course as a safety monitor and to assist the students and instructors. The facilitator would have to be more knowledgeable of the subject matter in this course than is typically the case in the CESN.

- The training equipment used in this and other laboratory courses must be adapted so that it is portable and can be taken in and out of classrooms that must be reused for other courses.

- Laboratory courses conducted by VTT require somewhat larger classrooms to accommodate demonstrations and other training equipment. Room power requirements should also be examined to accommodate equipment used in laboratory courses.

- Technology should be used to aid instructors and students. Supporting instructional technologies and equipment used in this research that should be part of an implementation of this course include the video microscope, the portable cameras, manual switch box, computer-based instruction, videotapes, and portable system carts. The switching system showing views of remote student workstations would be optional.

Decision Considerations and Liabilities

The extra effort to conduct this laboratory course by VTT combined with the small class size do not suggest much advantage for using VTT.

- Demands on VTT sites would be increased with this course. The VTT sites would incur greater demands on their resources in terms of facilitator assistance during classes, the logistics for preparing classrooms during each course convening, and for maintaining equipment and supplies.

- Initial costs for establishing VTT versions of courses can be a prohibitive when expensive training equipment must be duplicated at remote sites.

- Offering the Fiber Optic course by VTT would offer marginal savings in travel costs because of the small numbers of students per class. However, other laboratory courses with greater throughput could provide cost savings.

- The liabilities with offering the present course by VTT may not apply to other hands-on laboratory courses that could be delivered by VTT. VTT can be extended to laboratory courses on a case by case basis by examining the requirements of each candidate course and by generalizing the techniques and lessons learned from this effort.

Recommendations

The following recommendations are for the Commander, Naval Sea Systems Command, the Chief of Naval Education and Training, and the CNET Electronic Schoolhouse Network.

1. Experimental delivery of the Fiber Optic Cable Repair course by videoteletraining indicated that this method of delivery is feasible and could be attempted as a regular VTT offering.

2. The decision to offer this and other laboratory courses by VTT should weigh liabilities which include obtaining additional equipment for sites, the extra course support requirements on VTT site personnel, and the marginal cost savings when there are small numbers of students.

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Appendix A

ST Connector Check List

ST Connector Check List.

Step 1. Single fiber cable preparation lengths

1.1 Verified the type of fiber cable and connector.

Step 2. Single fiber cable preparation (R)

2.1 Slid the boot, small end first, onto cable.

2.2 Slid the silver metal sleeve on the cable.

2.3 Placed a piece of masking tape on the cable between the sleeve and the boot.

2.4 Used the ST template (not Biconic side) to determine the amount of jacketing to be removed from the cable.

2.5 Marked the cable at 1.1 or 1.25 inches from the cable end with the marking pen.

2.6 Used correct hole (B/middle slot) of wire strippers to remove jacketing back to the mark.

2.7 Trimmed the exposed kevlar fibers with the scissors, leaving about a quarter of an inch.

Step 3. Single buffered fiber preparation lengths (R)

3.1 Verified the correct length of buffer and fiber coating to be removed with the template.

Step 4. Buffered fiber preparation (R)

4.1 Inserts fiber into buffer removal tool until it bottomed out, then closes handles (.008 red insert; not .006 purple insert).

4.2 Looped cable once around fingers.

4.3 Pulled the fiber straight out of the tool with a slow, even pull (may do two small segments).

4.4 Removes excess from tool.

4.5 Removed remaining coating with a single wipe toward the end of the fiber with lint-free cloth and alcohol.

4.6 Wipes away toward the end of the fiber once.

4.7 Uses wet cloth and not dry cloth.

4.8 Avoids touching bare fiber with fingers.

4.9 Avoids letting fiber touch work surface.

4.10 Uses canned air to dry and separate the kevlar fibers (face can away)(**).

4.11 Placed the cable in a slot on the cooling block.

Step 5. Epoxy and Syringe preparation (O)(Students may share syringe)

5.1 Mixed the epoxy until the resin and hardener were blended and the mixture has a consistent, light tan appearance.

5.2 Removed protective cap from syringe.

5.3 Placed the injection tip securely on the syringe (should do before plunger).

5.4 Removed the plunger from the syringe.

5.5 Cut off corner of pouch containing the epoxy.

5.6 Poured/squeezed a small amount of epoxy into the barrel of the syringe.

5.7 Discarded the unused epoxy.

5.8 Replaced plunger and removed air from syringe by squeezing out a small amount of epoxy.

5.9 Backed off the plunger to prevent epoxy from leaking out.

Step 6. Connector assembly installation (R)

6.1 Inspected the connector channel for obstructions by holding the connector up to the light.

6.2 (**) If the connector was blocked, cleaned it out with a piece of 1.25 micron piano wire.

6.3 Inserted the syringe in the back of the connector until it bottoms out.

6.4 Injected epoxy until a small bead appears at the connector tip (then backs off plunger) (Students may share syringe).

6.5 (**) Immediately cleaned away epoxy that leaked onto the ceramic ferrule.

6.6 Inserted the fiber into the back of the connector until the cable was bottomed inside the connector and a length of bare fiber protruded from the tip.

6.7 Rotated connector to guide fiber into hole in ferrule.

6.8 (**) If necessary, reestablished the epoxy bead at the tip of the connector by sliding the epoxy down the fiber or by adding more epoxy from the syringe.

Step 7. Installing the cable sleeve (R)

7.1 Slid cable sleeve over outer jacket and trapped kevlar strength members inside connector barrel with cable sleeve firmly butted against connector body.

7.2 Crimped sleeve against outer jacket using B slot.

7.3 Rotated connector 90 degrees and crimped the sleeve a second time.

7.4 Placed the connector holder on the connector tip (step can be before 7.1).

7.5 Slid the boot up over the sleeve and screwed it on the connector body.

Step 8. Curing the epoxy (O)

8.1 Pre-heated the curing oven.

8.2 Placed the connector holder and connector into an oven port.

8.3 Allowed epoxy to cure in oven for 10 min.

8.4 Removed connector from oven & allowed it to cool on cooling block for 10 min.

Step 9. Cleaving the fiber (R)

9.1 Placed a piece of masking tape on the work area to dispose of the glass fragment.

9.2 Cleaved fiber with cleaving tool by lightly scoring fiber with tool just above the epoxy bead with a single motion (Errors: several scores, breaks fiber, control of sharp tool).

9.3 With thumb & forefinger, grasped end of fiber and pulled it directly away from connector.

9.4 Disposed of the glass fragment by pressing the fragment on the masking tape.

9.5 (**) Removed any excess epoxy from the ferrule with a razor.

Step 10. Pre-polishing (O) (once, no order)

10.1 Cleaned the polishing plate with lint-free cloth (using alcohol, till dry).

10.2 Cleaned the brown 5 micron paper with lint-free cloth and alcohol.

10.3 Optional: error: cleaned cable tip without breaking it by crossing end.

Step 11. Initial polishing (R)

11.1 Polished the connector with a constant figure-eight pattern (light pressure at first).

11.2 Cleaned the connector with a lint-free cloth and alcohol before inspecting the polish.

11.3 Inspected the connector through the 100 power magnifier.

11.4 Continued the initial polish until the connector face was free of epoxy.

Step 12. Final polish (R)

12.1 Replaced the brown 5 micron paper with the purple 1 micron paper.

12.2 Cleaned polishing plate with lint-free cloth.

12.3 Cleaned the purple 1 micron paper with lint-free cloth and alcohol.

12.4 Polished the connector with a constant figure-eight pattern.

12.5 Cleaned the connector before inspecting the polish.

12.6 Inspected the connector with the 100 power magnifier.

12.7 Continued the final polish until the connector face was free of epoxy and had a smooth, shiny appearance.

12.8 Placed the protective plastic cap on the end of the connector.

END: Instructor/Facilitator Tests Connector with OLTS (OBTAIN READINGS).

Note: "(R)" indicates step is repeated for each of two ends of connector.
"(O)" indicates step is commonly performed once.
"(**)" indicates step may or may not be performed.

Appendix B

Rotary Splice Connector Check List

Rotary Splice Check List.

Step 1. Buffered fiber preparation (R)

1.1 Strips off 6-7 inches of plastic jacketing with wire stripping tool.

1.2 Removes the jacketing in small pieces.

1.3 Trims off the kevlar strength members back to the jacketing.

1.4 Removes 3/4 of an inch of buffer and fiber coating with the buffer removal tool (using .008 red insert; not .006 purple insert).

1.5 Loops the cable once around his/her fingers.

1.6 Maintains a steady strain and pulls the cable straight out of the tool.

1.7 Cleans off remaining coating by wiping exposed glass once with lint-free cloth & alcohol.

1.8 Wipes toward the end of the fiber once.

1.9 Uses wet cloth (not dry cloth).

1.10 Avoids touching fiber with fingers.

1.11 Avoids allowing fiber to touch work surface.

1.12 Stores fiber in a slot on cooling block.

Step 2. Adhesive preparation (O)(Optional if students share)

2.1 Removes protective cap from syringe & places injector tip on the end (avoids mishandling).

Step 3. Ferrule preparation (R)

3.1 Separates ferrules by pulling them apart with light bending motion (no twist; clean break)(O).

3.2 Visually inspects the ferrule halves for obstructions in the fiber channel (R).

3.3 (**) Removes obstructions with piano wire (R).

3.4 Inserts the adhesive syringe into the back of the ferrule until it bottoms out (R).

3.5 Injects adhesive into the ferrule until a small bead forms at the tip of the ferrule (R).

Step 4. Fiber insertion (R)

4.1 Inserts the glass fiber into the back of the ferrule until about a quarter of an inch of fiber protrudes from the tip and the buffer is firmly butted inside of the ferrule (rotate OK).

4.2 (**) Restores the adhesive bead around the fiber at the tip of the ferrule.

Step 5. Curing the adhesive (R)

5.1 Places ferrule & inserted fiber cable into slot of UV curing tool (don't look at light).

5.2 Does not allow the fiber to touch the surface of the curing tray.

5.3 Fiber remains fully inserted in ferrule.

5.4 Turns on the UV curing lamp and places it over the curing tray.

5.5 Cures the ferrule-fiber assemblies for a minimum of 10 min. (depends on age of adhesive = 2-5-10-20 min).

Step 6. Cleaving and detaching the fiber (R)

6.1 Places a piece of masking tape onto the work surface to dispose of the cleaved glass fragment (O).

6.2 Scores the fiber just above the adhesive bead with a single swipe of the cleaving tool (R).

6.3 Grasps the excess fiber with the thumb and forefinger, and pulls it directly away from the end of the fiber (R).

6.4 Disposes of the fiber fragment on the masking tape (R).

6.5 Inspects the ferrule for dried adhesive on the ferrule (R).

6.6 (**) Removes excess adhesive with a razor blade (R).

Step 7. Pre-polishing (R)

7.1 Cleans all equipment used in the process with a lint free cloth and alcohol.

Step 8. Initial polishing (R)

8.1 Positions a piece of black 8 micron polishing paper on the polishing block.

8.2 Inserts the ferrule into the polishing puck and polishes the end of the ferrule with a light constant figure-8 pattern (uses square puck).

8.3 When the track on the polishing paper fades, stops polishing.

8.4 Cleans the ferrule and inspects the polish with the seven power loupe.

8.5 Continues to polish until the face of the ferrule is smooth and shiny.

Step 9. Final polishing (R)

9.1 Removes the black 8 micron paper from the polishing block, and replaces it with the white .3 micron polishing paper.

9.2 Cleans the polishing block and paper with a lint free cloth and alcohol.

9.3 Performs the polish using the figure-8 pattern.

9.4 When the track on the polishing paper fades, removes the ferrule from the puck and cleans it with a lint free cloth and alcohol.

Step 10. Inspecting the ferrule (R)

10.1 Inspects the polish with the seven power loupe.

10.2 Continues the polish until the face of the ferrule is smooth and shiny.

Step 11. Splice assembly (O)

11.1 Places the tip of the spring clip tool into the slot of the alignment sleeve and opens the sleeve by fully closing the handles on the tool.

11.2 Inserts one ferrule halfway into the sleeve.

11.3 Without releasing the pressure on the tool, inserts the second ferrule into the other end of the sleeve.

11.4 Centers the ferrules inside the sleeve before releasing the pressure on the spring and removing the tool.

Step 12. Index matching gel application (O)

12.1 Prepares index matching gel by mixing equal amounts of the ingredients in the two bottles on the glass mixing block (cleans dropper between bottles).

12.2 With a gentle twisting motion, pulls the ferrules apart inside the sleeve creating a gap of about one-sixteenth of an inch.

12.3 Places a drop of the mixture in the gap between the ferrules.

12.4 Closes the gap by gently rotating the ferrules together.

12.5 Aligns ferrules so that alignment tabs are in line with gap in the alignment sleeve.

Step 13. Splice alignment using 1011B tool (O)

13.1 Rotates the ferrules until the alignment tabs fit into the slots at the base of the 1011B splice alignment tool.

13.2 Optional: rotate ferrules until Optical Loss Test Set (OLTS) reading is the least.

Step 14. Securing the splice (O)

14.1 Uses the spring compression tool to pick up the splice assembly with the gap in the alignment sleeve facing down.

14.2 Places assembly into a slot in splice tray with gap pointing down at the bottom of the tray.

14.3 Arranges the fiber cables inside the tray and through the holes at the ends of the tray.

END: Instructor/Facilitator Tests Connector with OLTS (OBTAIN READINGS).

Note: "(R)" indicates step is repeated for each of two ends of connector.
"(O)" indicates step is commonly performed once.
"(**)" indicates step may or may not be performed.

Appendix C

Hughes Connector and Backshell Check List

Hughes-Backshell/Hughes-Connector Check List

Step 1. Connector Assembly

1.1 Slide on compression nut with boot onto cable.

1.2 Slide on shrink tubing onto cable.

1.3 Slide on strain relief housing onto cable.

1.4 Strip off 5 inches of outer cable jacketing.

1.5 Pull back strength members and tape onto cable.

1.6 Trim off filler members (if any).

1.7 Slide the compression ring over the strength members and down to the end of the cable.

1.8 Fold strength members back over compression ring toward strain relief housing, evenly distributed around ring.

1.9 Remove the O ring from the backshell.

1.10 Place the O-ring on the installation tool by sliding the O-ring on the small end of the cone.

1.11 Force O-ring up the cone to the larger end of the tool.

1.12 Slide O-ring tool over compression ring & strength member.

1.13 Roll O-ring off installation tool & over strength member.

1.14 Tape the strength members together to ease the installation of the compression nut.

1.15 Slide strain relief up to the cable to compression ring.

1.16 Gently feed the fibers and the strength members through the compression nut.

1.17 Thread the compression nut onto the strain relief coupling while pulling the kevlar taut.

1.18 Using the torque wrench and torque tool, tighten the compression nut to 25 in/lbs.

1.19 Remove tape from strength member and trim strength member down to the face of the compression nut.

Step 2. Stripping and Cleaning the Fibers

2.1 Slide the cable sleeves onto the fiber jackets.

2.2 Remove 1 & 6/32 inches of the individual fiber jackets down to the buffer.

2.3 Don't remove kevlar strength members (Error if done).

2.4 Mark each cable buffer at 3/4 inch.

2.5 Strip off the buffer coating from each fiber to the mark, using the buffer removal tool.

2.5.1 Do not apply lateral pressure on the cable while pulling it from the tool (Error if done).

2.5.2 Avoid breaking glass fiber in removing buffer (Error if done).

2.6 Remove stripped buffer from tool with tweezers.

2.7 Remove remaining coating from the glass fiber by wiping the fiber once with a lint-free cloth and alcohol.

2.7.1 Do not wipe the fiber more than once (Error if done).

2.7.2 Always wipe toward end of fiber (Error if not done).

2.7.3 Never wipe the fiber with a dry cloth (Error if done).

2.7.4 Avoid fiber touching work surface (Error if done).

2.7.5 Avoid touching glass fiber w/fingers (Error if done).

2.8 Preheat heating block by turning dial to 60 minutes.

2.8.1 Avoid contact with the heating block (Error if done).

Step 3. Epoxy and Syringe Preparation

3.1 Clean the termini by soaking them in propanol for 3 to 5 minutes.

3.2 Inspect the termini to ensure that nothing is blocking the fiber path.

3.3 Dry the termini with low pressure air.

3.3.1 Do not direct pressurized air toward eyes or other persons.

3.4 Prepare epoxy according to manufacturer's instructions.

3.5 Attach insertion tip onto the syringe.

3.6 Remove the plunger from the syringe and pour epoxy into the barrel.

3.7 Reinsert the plunger into the syringe and remove air by squeezing out epoxy onto a cloth.

3.8 Insert the needle into the base of the contact until it bottoms out, and inject epoxy into the contact until a bead forms at the tip.

3.9 Remove the needle from the contact and wipe away excess epoxy from the contact.

3.10 Slide the cable sleeve up to the strength member.

3.11 Feather strength member evenly around cable sleeve.

3.12 Insert the fiber into the back of the contact until the fiber protrudes from the tip and the buffer is in contact with the shoulder of the contact.

3.13 If necessary, reestablish the epoxy bead at the tip of the termini.

3.14 Slide the cable sleeve over the kevlar fibers and against the base of the termini body.

3.15 Crimp the sleeve to the termini with the crimp tool.

3.15.1 Use the correct hole in the crimp tool.

3.16 Rotate the termini 90 degrees and crimp again (Different from the Veam procedure).

3.17 Trim the strength members as close to the cable sleeve as possible (Different from the Veam procedure).

3.18 Fit the contact onto the curing fixture of the heating oven.

3.19 Clamp the strain into place.

3.20 Cure the termini on the heating block for 1 hour.

3.21 Release the contacts form the curing fixture with tweezers.

3.22 Release cable from clamp on the heating block.

3.23 Cleave the exposed fiber by scoring the side of the fiber with the cleaving tool.

3.24 Remove the fiber by grasping the end of the fiber with thumb and forefinger and pulling it straight away from the termini.

3.25 Dispose of fiber fragment on a piece of masking tape.

Step 4. Grinding & Polishing Fiber Optic Contacts

4.1 Place the strain relief and the cable in the adjustable strain relief support and tighten the screw (Different from the Veam procedure).

4.2 Turn the lower polishing face assembly counter clockwise and remove it from the carrier fixture.

4.2.1 If necessary, remove excess epoxy from the termini with a razor blade.

4.3 Insert the contact to be ground and polished into the center hole of the carrier and insert it into place with the contact insertion tool.

4.4 Insert the remaining termini into the holes on the top of the carrier.

4.5 Reattach the lower face of the polishing fixture.

4.5.1 Do not damage the exposed fiber and bead while reattaching the lower half of the carrier.

4.6 Clean the polishing plate and polishing paper.

4.7 Place a piece of 5 micron polishing paper on the polishing plate.

4.8 Polish the termini using a figure-8 pattern and very light pressure until the track on the paper fades and no further resistance is felt.

4.9 Clean the termini with a lint-free cloth and alcohol.

4.10 Inspect the polish.

4.11 Continue to polish termini until the face of the termini is free of epoxy and has a smooth shiny appearance.

Step 5. Insert Assembly

5.1 Slide the shrink tube over the knurled end of the strain relief and up to the shoulder.

5.2 Starting at strain relief, use heat gun to shrink the tubing.

5.3 Fit the insert to the strain relief by snapping spacing shafts into the three notches in the face of the strain relief.

Step 6. Contact Insertion

6.1 Place contact insertion tool over base of the termini.

6.2 Place the termini into the proper channel and press on the insertion tool until it snaps into place.

6.3 If inserting a female connector, use alignment sleeve tool to seat an alignment

sleeve over end of the termini.

Step 7. Final Assembly of the Backshell

7.1 Slide the insert into the shell assembly.

7.2 When bottomed, rotates the backshell until the keyway lines up with the insert, then seat the insert.

7.3 Slide the compression nut and boot up the cable and thread the nut onto the backshell.

7.4 Tighten the nut with the torque wrench to 60 in/lbs.

Step 8. Contact Removal

8.1 Remove the alignment sleeves from the ends of the female termini with the alignment sleeve tool.

8.2 Insert the contact removal tool over the end of the termini until it seats into place, then press the plunger and slide the contact from the terminal block.

END: Instructor/Facilitator Tests Connector with OLTS (OBTAIN READINGS).

Appendix D

Safety and Work Product Ratings

Safety and Work Product Check Lists for Connector Laboratories

Safety Check List:
Circle Ratings using these Codes (R = Rarely   M = Mostly   A = AlmostAlways)

1. Wore protective eye gear when required during the procedure	R M A
2. Careful with liquids: epoxy adhesive [ST, Hughes] Careful with liquids: UV adhesive & matching gel [Rotary]	R M A
3. Pointed canned air away from work area, self, and other persons (optional if used)	R M A
4. Did not touch the exposed bare glass fiber with fingers other than required	R M A
5. Maintained control of glass fiber fragments	R M A
6. Did not touch heated connectors with bare fingers [ST, Hughes] Did not look directly into UV light (Rotary)	R M A

Work and Product Check List:
Check or Circle Rating at Right

1. Broken fiber during cleaving	Twice___ Once___ No___
2. Broken fiber by mishandling	Twice___ Once___ No___
3. Shattered fiber shown visually	Twice___ Once___ No___
4. Connector damage or not secure	Yes___ Marginal___ No___
5. Poor polish quality visually	Yes___ Marginal___ No___
6. Bad work product requires repeat steps	Yes___ Marginal___ No___
7. Poor cleaning practices (fiber, connector, polish paper, alcohol)	Yes___ Marginal___ No___
8. Excessive amount of light loss	Yes___ Marginal___ No___
9. Light loss readings: Connector # 1	________________ db loss
10. Light loss readings: Connector # 2	________________ db loss

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Note: The safety check list had alternative versions of items 2 and 6 which were applicable to the connector indicated in brackets.

Note: Data analyses were conducted by assigning the numbers 1, 2, and 3 as follows:
Safety: R=1, M=2, A=3;
Work product items 1 through 3: Twice=1, Once=2, No=3;
Work product items 4 through 8: Yes=1, Marginal=2, No=3.

Table D-1
ST Connector Laboratory Safety Rating Frequencies

Rating Item	Rating Category	Traditional	Local	Remote
1. Wore protective eye gear when required during the procedure	(1) Rarely	1	1	1
	(2) Mostly	5	4	2
	(3) Almost Always	12	11	13
2. Careful with liquids (epoxy adhesive)	(1) Rarely	0	0	0
	(2) Mostly	3	1	1
	(3) Almost Always	15	15	15
3. Pointed canned air away from work area, self, and other persons (optional if used)	(1) Rarely	0	0	0
	(2) Mostly	0	0	0
	(3) Almost Always	1	9	10
	Not Applicable	17	7	6
4. Did not touch the exposed bare glass fiber with fingers other than required	(1) Rarely	0	0	0
	(2) Mostly	1	3	0
	(3) Almost Always	17	13	16
5. Maintained control of glass fiber fragments	(1) Rarely	1	0	2
	(2) Mostly	4	5	0
	(3) Almost Always	13	11	14
6. Did not touch heated connectors with bare fingers	(1) Rarely	0	0	0
	(2) Mostly	1	3	2
	(3) Almost Always	17	13	14
Number of Students Per Group		18	16	16

Numbers in parentheses are values assigned to compute mean ratings in Figures 6 and 7.
Entries in table are number of students receiving the rating.

Table D-2
Rotary Splice Connector Laboratory Safety Rating Frequencies

Rating Item	Rating Category	Traditional	Local	Remote
1. Wore protective eye gear when required during the procedure	(1) Rarely	2	1	0
	(2) Mostly	4	6	7
	(3) Almost Always	12	9	9
2. Careful with liquids (UV adhesive & matching gel)	(1) Rarely	0	0	0
	(2) Mostly	2	2	3
	(3) Almost Always	16	14	13
3. Pointed canned air away from work area, self, and other persons (optional if used)	(1) Rarely	0	0	0
	(2) Mostly	0	0	0
	(3) Almost Always	0	8	6
	Not Applicable	18	8	10
4. Did not touch the exposed bare glass fiber with fingers other than required	(1) Rarely	0	0	0
	(2) Mostly	3	1	0
	(3) Almost Always	15	15	16
5. Maintained control of glass fiber fragments	(1) Rarely	2	1	1
	(2) Mostly	2	2	4
	(3) Almost Always	14	13	11
6. Did not look directly into UV light	(1) Rarely	0	0	0
	(2) Mostly	0	0	2
	(3) Almost Always	18	16	14
Number of Students Per Group		18	16	16

Numbers in parentheses are values assigned to compute mean ratings in Figures 6 and 7.
Entries in table are number of students receiving the rating.

Table D-3
ST Connector Work Product Rating Frequencies

Rating Item	Rating Category	Traditional	Local	Remote
1. Broken fiber during cleaving				
	(1) Twice	1	1	1
	(2) Once	6	2	4
	(3) No	11	13	11
2. Broken fiber by mishandling				
	(1) Twice	0	0	0
	(2) Once	4	2	1
	(3) No	14	14	15
3. Shattered fiber shown visually				
	(1) Twice	0	0	1
	(2) Once	2	4	4
	(3) No	16	12	11
4. Connector damage or not secure				
	(1) Yes	0	1	0
	(2) Marginal	1	1	0
	(3) No	17	14	16
5. Poor polish quality visually				
	(1) Yes	0	0	0
	(2) Marginal	1	2	2
	(3) No	17	14	14
6. Bad work product requires repeat steps				
	(1) Yes	2	0	2
	(2) Marginal	5	1	2
	(3) No	11	15	12
7. Poot cleaning practices (fiber, connector, polish paper, alcohol)	(1) Yes	3	0	2
	(2) Marginal	2	0	0
	(3) No	13	16	14
8. Excessive amount of light loss				
	(1) Yes	2	5	5
	(2) Marginal	1	1	1
	(3) No	15	10	10
Number of Students Per Group		18	16	16

Numbers in parentheses are values assigned to compute mean ratings in Figures 6 and 7.
Entries in table are number of students receiving the rating.

Table D-4
Rotary Splice Connector Work Product Rating Frequencies

Rating Item	Rating Category	Traditional	Local	Remote
1. Broken fiber during cleaving				
	(1) Twice	1	0	0
	(2) Once	2	2	3
	(3) No	15	14	13
2. Broken fiber by mishandling				
	(1) Twice	0	0	1
	(2) Once	3	2	0
	(3) No	15	14	15
3. Shattered fiber shown visually				
	(1) Twice	0	0	0
	(2) Once	4	1	1
	(3) No	14	15	15
4. Connector damage or not secure				
	(1) Yes	4	1	3
	(2) Marginal	2	0	1
	(3) No	12	15	12
5. Poor polish quality visually				
	(1) Yes	1	0	2
	(2) Marginal	3	1	1
	(3) No	14	15	13
6. Bad work product requires repeat steps				
	(1) Yes	4	1	2
	(2) Marginal	5	5	6
	(3) No	9	10	8
7. Poot cleaning practices (fiber, connector, polish paper, alcohol)	(1) Yes	0	0	1
	(2) Marginal	8	0	1
	(3) No	10	16	14
8(L). Excessive amount of light loss (Laboratory Method)	(1) Yes	5	4	4
	(2) Marginal	3	2	0
	(3) No	10	10	12
8(D). Excessive amount of light loss (Difference Method)	(1) Yes	7	6	6
	(2) Marginal	3	2	2
	(3) No	8	8	8
Number of Students Per Group		18	16	16

Numbers in parentheses are values assigned to compute mean ratings in Figures 6 and 7.
Entries in table are number of students receiving the rating.

Appendix E

Interaction Tally Categories and Summary Statistics

VTT Interaction Tally Categories

An observer recorded the frequency of interactions that occurred over the VTT network in the categories given below. Interactions had to be related to course content. Start and end times for each class period were recorded on the tally form to account for variations of these periods over different class convenings. For each of the first five categories below, a check mark was entered in a box corresponding to whether it occurred at the local site or at the remote site.

Instructor questions (Categories 1-3):

(1) Instructor question open to any site: Instructor asks a question (and receives an answer) in which no site is identified so that all sites are free to respond to the question.

(2) Instructor question names a site: Instructor asks a question (and receives an answer) that identifies a site which should answer, either the local site, a specific remote site, or "any" remote site.

(3) Instructor questions specific student: Instructor asks a question (and receives an answer) directed at one student by singling out the student by name, title, or by pointing (a class roster for each site was created during the first morning of the class).

Student questions (Categories 4-5):

(4) Student initiated question: A student initiates a question to the instructor, class, or another student.

(5) Student conversations and exchanges: Student exchanges, comments, or general conversations involving continued back-and-forth exchanges on an issue, such as to resolve a problem. These were most commonly a continuation of a student initiated question that resulted in more than one communication each for the instructor and student, including another student than the one initiating the original question.

Unanswered questions and microphone reminders (Categories 6-8):

Several other miscellaneous circumstances were recorded separately in addition to the above categories. These were recorded for the whole class and not by remote and local sites, or only for local students in the case of category 8:

(6) No answer to question: There was No Answer from students to an instructor question which was specific to the instructional content.

(7) No answer to generic request for questions: The instructor asked in one way or another if there were "Any Questions" and no response was received from the students. These questions were generic queries that were used to pause before proceeding with the instruction.

(8) Reminders to local students to use microphones: The instructor reminded the local San Diego site to use the microphones so remote sites could hear questions and comments.

Table E-1
Instructor and Student Interaction Rates

Measure and Group	Lectures		Demonstrations		Laboratories	
	Local	Remote	Local	Remote	Local	Remote
Number of students (S)	16	16	16	16	16	16
Students per class (S/C)	4	4	4	4	4	4
Total recording hours (H)	13.67	13.67	14.08	14.08	23.99	23.99
Recording hours per class (H/C)	3.41	3.41	3.52	3.52	5.99	5.99
Interaction Frequencies (I)						
All instructor (1-3)	100	136	93	107	3	53
All student (4-5)	94	64	98	82	14	212
All instructor and student (1-5)	194	200	191	189	17	265
Interactions Per Hour (I/H)						
Instructor Questions:						
(1) Open to any site	4.38	3.58	5.46	4.19	0.04	0.04
(2) Names a site	0.29	3.65	0.07	2.55	0.04	1.46
(3) Specific student	2.63	2.70	0.99	0.85	0.04	0.70
Student Questions:						
(4) Student initiated	4.02	2.56	5.25	3.40	0.50	6.80
(5) Conversations/exchanges	2.85	2.12	1.70	2.41	0.08	2.04
All instructor (1-3)	7.31	9.94	6.60	7.59	0.12	2.21
All student (4-5)	6.87	4.68	6.96	5.82	0.58	8.84
All instructor and student (1-5)	14.19	14.63	13.56	13.42	0.70	11.05
Interactions Per Hour Per Student (I/H)/(S/C)						
Instructor Questions:						
(1) Open to any site	1.09	0.89	1.36	1.04	0.01	0.01
(2) Names a site	0.07	0.91	0.01	0.63	0.01	0.36
(3) Specific student	0.65	0.67	0.24	0.21	0.01	0.17
Student Questions:						
(4) Student initiated	1.00	0.64	1.31	0.85	0.12	1.70
(5) Conversations/exchanges	0.71	0.53	0.42	0.60	0.02	0.51
All instructor (1-3)	1.82	2.48	1.65	1.90	0.03	0.55
All student (4-5)	1.71	1.17	1.74	1.45	0.14	2.21
All instructor and student (1-5)	3.54	3.65	3.39	3.35	0.17	2.76

Note: See Table E-3 for symbols and formulas used. Lectures were all on first day of class. Four instructor demonstrations and the four corresponding student laboratories are each combined in the table (ST, Rotary, Hughes, and test equipment).

Table E-2
Interaction Rates for Unanswered Questions and Microphone Reminders

Measure	Lectures	Demos	Labs
Interactions Per Hour (I/H)			
(6) No answer to instructor question	0.36	0.71	0.16
(7) No answer to "any questions" query	4.17	1.91	0.08
(8) Microphone reminders to local students	0.65	0.42	0.08
Interactions Per Hour Per Student (I/H)/(S/C)			
(6) No answer to instructor question	0.04	0.08	0.02
(7) No answer to "any questions" query	0.52	0.24	0.01
(8) Microphone reminders to local students	0.16	0.10	0.02

Note: Unanswered questions for categories (6) and (7) are for both classrooms combined, microphones reminders for category (8) are for local classroom only.

Table E-3
Symbols and Formulas Used in Interaction Rate Computations

I	=	Sum of number of interactions over four classes
H	=	Total recording hours over four classes
C	=	Number of classes
S	=	Total number of students over four classes
S/C	=	Students per class
H/C	=	Recording hours per class
I/H	=	Interactions per hour
(I/H)/(S/C)	=	Interactions per hour per student (per class)
(I/H)/(S/C)	=	(I/S)/(H/C) = [(I/C)/(H/C)]/(S/C)

Table E-4
Interaction Raw Frequencies for Class Activities

Class Activity, Day, and Treatment Group	(1) Any Site	(2) Name Site	(3) One Stu	(4) Stu Init	(5) Stu Conv	(6) No Ans	(7) Any Ques	(8) Mics Local	Total Rec. Hrs.
	Interaction Categories and Recording Hours								
After Videotapes (Mon)									
Local	1	1	0	4	4	1	4	3	1.05
Remote	2	12	1	10	5	"	"	-	1.05
Lecture (Mon)									
Local*	60	4	36	55	39	5	57	9	13.67
Remote*	49	50	37	35	29	"	"	-	13.67
Traditional	79	0	7	30	17	7	31	-	7.13
ST Demonstration (Tue)									
Local*	8	1	2	12	4	2	4	1	3.78
Remote*	18	17	3	6	6	"	"	-	3.78
Traditional	20	0	4	20	4	1	5	-	1.67
ST Student Laboratory (Tue)									
Local*	1	0	0	6	2	4	1	2	6.95
Remote*	1	13	9	76	22	"	"	-	6.95
Traditional	6	0	3	39	18	0	0	-	3.85
Rotary Demonstration (Tue)									
Local*	8	0	1	6	0	4	4	1	2.70
Remote*	9	4	4	10	3	"	"	-	2.70
Traditional	9	0	0	28	10	1	5	-	1.50
Rotary Student Laboratory (Tue)									
Local*	0	0	0	4	0	0	0	0	8.52
Remote*	0	7	6	44	7	"	"	-	8.52
Traditional	1	0	0	25	19	0	0	-	3.33
Hughes Demonstration (Wed)									
Local*	4	0	1	10	8	1	12	2	2.72
Remote*	8	1	0	9	10	"	"	-	2.72
Traditional	10	0	0	23	17	0	6	-	1.18

Table E-4 Continued

Activity/Group	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Hrs.
Hughes Student Laboratory (Wed)									
Local*	0	0	0	1	0	0	0	0	2.78
Remote*	0	6	1	18	8	"	"	-	2.78
Traditional (1 class)	0	0	0	6	3	0	0	-	0.67
Test Equipment and Trouble-Shooting Lecture/Demonstration (Wed)									
Local*	57	0	10	46	12	3	7	2	4.88
Remote*	24	14	5	23	15	"	"	-	4.88
Traditional	14	0	11	18	17	1	2	-	1.90
Test Equipment and Trouble-Shooting Student Laboratory (Wed)									
Local*	0	1	1	1	0	0	1	0	5.72
Remote*	0	9	1	25	12	"	"	-	5.72
Traditional	2	0	0	20	4	0	0	-	2.05
Instructor Led Homework Review (Thu)									
Local	11	1	102	16	35	1	7	5	3.65
Remote	8	6	109	19	34	"	"	-	3.65
Traditional	8	0	88	9	9	1	1	-	1.05
Trouble-Shooting Performance Test (Thu) (hours averaged appropriate to 2 tests)									
Local	1	0	0	1	0	2	3	0	7.85
Remote	1	7	3	64	28	"	"	-	7.85
Traditional	0	0	26	117	29	0	0	-	3.57
Test Question/Answer Session (Fri)									
Local	22	1	3	11	31	0	1	1	1.47
Remote	14	2	1	11	16	"	"	-	1.47
Traditional	16	0	0	13	4	1	1	-	0.72

Note: Table entries are the sum of 4 VTT classes (16 local and 16 remote students) or sum of 2 traditional classes (18 students; the Hughes laboratory was conducted for only one class). Interaction categories 1-8 are as described at the start of the appendix. Categories 6 and 7 are combined data for local and remote ("). Category 8 only applied to local students (-). Data used in formal analysis in previous tables are shown with an asterisk (*). Other data in this table were not included in the analysis because some class periods were brief or involved activities other than lectures, demonstrations, and laboratories. Data for traditional classes were not comparable to those for VTT classes because VTT data only included interactions over the VTT network and not those within the room, whereas traditional data included within room interactions.

Appendix F
Student Questionnaire

FIBER OPTIC COURSE STUDENT QUESTIONNAIRE

a. Name________________________ ________________ _______ ____________
Last First MI Rank

b. Today's date______________________ c. Location [ ] With Instructor
[ ] Remote Classroom

For each of the statements followed by [1] [2] [3] [4] [5] , please check the box indicating how well you agree with the statement using this scale:

[1]	[2]	[3]	[4]	[5]
Strongly Disagree	Disagree	Neither Agree/ Disagree	Agree	Strongly Agree

---

BACKGROUND	Disagree SD	D	N	A	Agree SA
1. Before this course, I had basic knowledge of fiber optic concepts and facts	[1]	[2]	[3]	[4]	[5]
2. Before this course, I was proficient at performing the fiber optic cable repair tasks	[1]	[2]	[3]	[4]	[5]
3. Before this course, I was proficient at performing the fiber optic trouble shooting tasks	[1]	[2]	[3]	[4]	[5]

INSTRUCTORS	Disagree SD	D	N	A	Agree SA
4. Instructor was prepared & presented lessons clearly	[1]	[2]	[3]	[4]	[5]
5. Instructor encouraged class participation	[1]	[2]	[3]	[4]	[5]
6. Instructor answered student questions adequately	[1]	[2]	[3]	[4]	[5]
7. Instructor helped students who needed assistance	[1]	[2]	[3]	[4]	[5]
8. Instructor maintained adequate control of class	[1]	[2]	[3]	[4]	[5]

LEARNING & CLASSROOM ACTIVITIES	Disagree SD	D	N	A	Agree SA
9. I could see the instruction clearly	[1]	[2]	[3]	[4]	[5]
10. I could hear the instruction clearly	[1]	[2]	[3]	[4]	[5]
11. Lecture/theory part of class was adequate	[1]	[2]	[3]	[4]	[5]
12. Demonstrations of procedures were adequate	[1]	[2]	[3]	[4]	[5]
13. Cable/connector repair laboratories were accomplished without problems	[1]	[2]	[3]	[4]	[5]
14. Test equipment (OTDR/OLTS) used without problems	[1]	[2]	[3]	[4]	[5]
15. Trouble shooting laboratory could be accomplished without problems	[1]	[2]	[3]	[4]	[5]
16. Course safety procedures were adequate	[1]	[2]	[3]	[4]	[5]

TRAINING AIDS

	SD (Disagree)	D	N	A	SA (Agree)
17. Details of training aids and demonstrations could be clearly seen	[1]	[2]	[3]	[4]	[5]
18. Slides/transparencies/graphics were readable	[1]	[2]	[3]	[4]	[5]
19. Room layout and table space were adequate	[1]	[2]	[3]	[4]	[5]
20. The film/videotape was informative	[1]	[2]	[3]	[4]	[5]
21. The film/videotape was clearly seen and heard	[1]	[2]	[3]	[4]	[5]
22. Microscopic camera setup was useful in allowing cable/connector repair work to be inspected	[1]	[2]	[3]	[4]	[5]
23. Computer-based trouble-shooting problems were useful	[1]	[2]	[3]	[4]	[5]

How many problems did you work through using the computer-based trouble-shooting program? ______ Number of problems

How much clock time did you spend using the computer-based trouble-shooting program? ____:____ hrs:minutes

INTERACTION/PARTICIPATION

	SD (Disagree)	D	N	A	SA (Agree)
24. Interaction between instructors and students was sufficient to support learning objectives	[1]	[2]	[3]	[4]	[5]
25. Class participation was sufficient to support learning objectives	[1]	[2]	[3]	[4]	[5]
26. Students aided one another in performing tasks	[1]	[2]	[3]	[4]	[5]
27. Instructor gave equal attention to all students	[1]	[2]	[3]	[4]	[5]
28. I hesitated to ask questions in order to clarify concepts or steps in the procedures	[1]	[2]	[3]	[4]	[5]
29. I received help on problems when I needed it	[1]	[2]	[3]	[4]	[5]

OVERALL

	SD (Disagree)	D	N	A	SA (Agree)
30. Instructor(s) compare favorably with the best Navy instructors I have had in the past	[1]	[2]	[3]	[4]	[5]
31. This course compares favorably with the best Navy courses I have taken in the past	[1]	[2]	[3]	[4]	[5]
32. The course provided skills that will be useful on the job	[1]	[2]	[3]	[4]	[5]
33. I found the course material to be difficult	[1]	[2]	[3]	[4]	[5]

34. The pace of the course was:

[ ]	[ ]	[ ]	[ ]	[ ]
Too-Slow	Somewhat-Slow	About-right	Somewhat-Fast	Too-Fast

ADEQUACY OF PORTIONS OF COURSE

Please rate the extent to which different portions of this course could be accomplished effectively:

	Disagree SD	D	N	A	Agree SA
35. Lectures	[1]	[2]	[3]	[4]	[5]
36. Instructor demonstrations of cable repair	[1]	[2]	[3]	[4]	[5]
37. Videotaped demonstrations of cable repair	[1]	[2]	[3]	[4]	[5]
38. My own cable repair work with ST, Rotary Splice and Veam/Hughes connectors	[1]	[2]	[3]	[4]	[5]
39. Instructor demonstrations of OLTS/OTDR and trouble shooting of cable system	[1]	[2]	[3]	[4]	[5]
40. My work with OLTS/OTDR and trouble shooting the cable system	[1]	[2]	[3]	[4]	[5]
41. Ability of students to get help	[1]	[2]	[3]	[4]	[5]

VIDEO-TELETRAINING	Disagree SD	D	N	A	Agree SA
42. Instructor coordinated activities among classroom sites effectively	[1]	[2]	[3]	[4]	[5]
43. Local and remote site classrooms participated equally in the class	[1]	[2]	[3]	[4]	[5]
44. The instructor called on students at all of the sites about equally	[1]	[2]	[3]	[4]	[5]
45. The VTT facilitators assisting the instructor were helpful to students in the class	[1]	[2]	[3]	[4]	[5]
46. Switching among camera views of remote-site students provided a beneficial "remote presence"	[1]	[2]	[3]	[4]	[5]

47. Who most frequently provided assistance to you:
    - [ ] Instructor
    - [ ] Facilitator
    - [ ] Other students
    - [ ] Other (please explain): ____________________

48. Which method of instruction would you prefer for this course:
    - [ ] Video Tele-Training (VTT)
    - [ ] Traditional method (non-VTT)
    - [ ] Either method

49. How did the VTT method of instruction affect your opportunities to interact with the instructor?
    - [ ] more opportunities
    - [ ] no effect on opportunities
    - [ ] fewer opportunities

50. If you had a choice, would you take another VTT course?

[ ] Yes

[ ] No

Please explain either answer:____

COMMENTS: Please answer the following questions by writing in your comments on the blank lines.

51. What did you like the most about this course?__________________________

52. What did you like the least about this course?__________________________

53. Discuss any suggestions you have for improving the course_______________

Abbreviated Version of
Fiber Optic Course Student Questionnaire
Used for Traditional Courses

The questionnaire given in the preceding pages was the full version of the student questionnaire given to VTT classes. An abbreviated version of the same questionnaire was given to Traditional classes. This abbreviated version was modified to omit items 20-23, 37, 42-47, and 49-50. For item 48, a short paragraph describing VTT prefaced the question so that students could judge their preference for a method of instruction. The revised version of this question is as follows:

```
This course is also given by Video Tele-training (VTT), where some
students are at a remote site (TI & Bangor) and provided an interactive
TV system to watch, hear and interact with the instructor giving the
class in San Diego.  The next question refers to this method of
instruction and the one you are currently receiving.

  48. Which method of instruction would you prefer for this course:
         [ ] Video Tele-Training (VTT)
         [ ] Traditional method  (non-VTT)
         [ ] Either method
```

Appendix G

Connector Error Summary Tables and Figures

Table G-1
Error Types and Abbreviations within Four Error Groups

Error Type Abbreviation	Error Group and Error Type Description
	Error Group: Critical to Work Product
B	Broken fiber
D	Connector damage, not secure, or broken
Sh	Shatter shown, scratched or damaged ferrule face
Tc	Technique critical to product
Lc	Length preparation problem critical to product
	Error Group: Fiber Care, Mishandling, Safety
Fc	Fiber care and mishandling
Sa	Safety
Sg	Safety glasses at any step
	Error Group: Technique, Length Preparation, General Cleaning and Liquids Care
T	Technique, general technique not critical to product
L	Length preparation problem
Cg	Cleaning: general cleaning and care with liquids
	Error Group: Polishing and Cleaning Directly Affecting Polish Decision
P	Polishing, repolishing to overcome problem, and difficulty deciding when polish is completed
Cp	Cleaning directly affecting polish (cleaning connector before inspecting polish)

Note: Error type abbreviations are used in subsequent tables and figures.

Note: Terminology used is as follows: *Individual errors* are the lowest level of data reflecting the individual procedural "steps" as given in the observer checklists in Appendices A and B. Four *phases* resulted from dividing the linear sequence of the procedural steps in terms of logical breaks where a subgoal was achieved. There are 13 *error types* that resulted from categorizing the individual errors that were highly similar to one another (see Tables G-2 and G-3). *Groups* of errors are a combination of the error types into four broad clusters. This categorization was designed to isolate two error groups that contained more serious errors (i.e., the critical to work product and fiber care error groups) from two other less serious error groups (i.e., the technique and polishing error groups). Some individual errors could be classified in more than one "error type" category, but those error types all fell within the same "grouping" of errors.

Table G-2
Individual ST Connector Errors by Phase and Error Type

Error Number	Error Type	Description of Phase and Individual Error Type
		Phase A (Steps 1-4): Fiber preparation, removal of jacketing and buffer in correct lengths
1	T	Put boot, sleeve, masking tape on later instead of at start
2	L	Used wrong side of ST template for measuring (used Biconic side)
3	L	Does not mark cable with length prior to stripping
4	Fc	Bends cable excessively when using wire strippers
5	L	Removes wrong amount of jacketing with strippers, repeats steps later
6	L	Trims kevlar fibers to wrong length
7	L	Fails to verify if correct length of jacketing and kevlar removed
8	B	Breaks fiber while using buffer removal tool
9	T	Struggle with Buffer tool or incorrect use or technique
10	Lc	Does not remove enough buffer with buffer removal tool
11	Cg	Does not wipe fiber with lint free cloth and alcohol
12	Cg	Wipes fiber end several times
13	Sa	Touches bare fiber with fingers
14	Fc	Lets fiber touch work surface or dropped
15	Fc	Does not place cable in slot on cooling block
		Phase B (Steps 5-8): Epoxy preparation, injecting epoxy, inserting fiber, installing cable sleeve, crimping connector, and curing epoxy in oven
16	Cg(T)	Did not back off syringe plunger to prevent epoxy from leaking out
17	T	Does not inspect connector channel for obstructions by holding up to light
18	Fc	Forces fiber into channel to check for obstructions
19	B	Breaks fiber during insertion into connector
20	T	Does not rotate fiber when inserting into connector when encountering difficulty
21	Tc	Does not inject epoxy into connector before crimping, causing repeat steps later
22	Cg(T)	Excess epoxy on ceramic ferrule
23	T	Does not reestablish epoxy bead at tip of connector after repositioning fiber
24	B	Breaks fiber while installing cable sleeve
25	D	Connector damage using crimping tool from sleeve or cable not fully seated or poorly afixed
26	Tc	Crimps connector once instead of rotating and crimping twice
27	Fc	Fails to put connector holder on to protect exposed fiber
28	T	Minor technique: Curing one connector end instead of curing both at same time
		Phase C (Step 9): Cleaving, detaching and disposing of fiber
29	Sa	Does not use masking tape in disposing of glass fiber fragment
30	Tc	Cleaves fiber before curing epoxy in oven
31	T	Cleaves/scores fiber several times but without breaking fiber
32	B	Breaks fiber during cleaving
33	T	Trouble grasping fiber to pull it straight away from connector after cleaving
34	B	Breaks fiber by not pulling straight away from connector after cleaving

		Phase D (Steps 10-12): Initial and final polishing and testing product
35	Cg	Does not clean either polishing plate or paper with alcohol
36	T	Uses wrong side of polishing paper until corrected
37	B	Snags or shatters fiber in initial polish because fiber too long and too much pressure
38	Cp	Does not clean connector with alcohol and cloth prior to inspecting polish
39	Sh(D)	Discovers shattered fiber or scratched ferrule face during inspection
40	P	Repolishing to overcome problem and difficulty deciding when polish is done
		All Phases (Steps 1-12 for Phases A, B, C, and D):
41	Sg	Not wearing safety glasses at some point during all phases

Note: Error types in parenthesis indicate a secondary classification that was not used, e.g., Cg(T) and Sh(D). Individual types of errors are only approximately in linear order within the sequential phases and are derived from the observer checklist given in Appendix A.

Table G-3
Individual Rotary Splice Connector Errors by Phase and Error Type

Error Number	Error Type	Description of Phase and Individual Error Type
		Phase A (Step 1): Fiber preparation removal of jacketing and buffer in correct lengths
1	L	Strips off too little plastic jacketing with wire stripping tool
2	T	Poor technique in removing small pieces of jacketing with wire stripping tool
3	Lc	Does not remove enough buffer with buffer removal tool
4	B	Breaks fiber while using buffer removal tool
5	T	Uses wrong buffer tool blade insert, but corrects problem
6	T	Does not use steady strain in pulling out of buffer tool (too quickly, awkwardly)
7	Cg	Does not wipe glass fiber or use alcohol to wet cloth
8	Cg	Wipes fiber several times
9	Fc	Allows fiber to touch work surface
10	Fc	Does not store fiber in cooling block slot
		Phase B (Steps 2-5): Adhesive & ferrule preparation, injecting adhesive, inserting fiber, curing adhesive under ultraviolet lamp
11	T	Does not visually inspect ferrule halves for obstructions
12	Tc	Encounters problem when inserting fiber because did not visually inspect
13	Cg	Squirts too much UV adhesive from syringe and drips on table
14	Cg(T)	Injects too much UV adhesive into ferrule and adhesive covers or runs down ferrule
15	B	Breaks fiber inserting into ferrule or because not fully inserted
16	L	Encounters problem inserting fiber because not enough fiber exposed
17	Fc	Allows fiber to touch work surface or drops fiber
18	B	Breaks fiber carrying to UV lamp and has to repeat steps
19	Tc	Does not cure UV adhesive long enough and fiber is insecure or comes out later

		Phase C (Step 6): Cleaving, detaching and disposing of fiber
20	Sa	Does not use masking tape in disposing of glass fiber fragment
21	Sa	Looses fiber fragment so cannot dispose of properly
22	T	Cleaves/scores fiber several times but without breaking fiber
23	B	Breaks fiber during cleaving
24	Fc	Drops cable during cleaving fiber
25	T	Trouble grasping fiber when attempting to pull it straight away from connector after cleaving
26	B	Breaks fiber pulling straight away from connector after cleaving
27	T(Cg)	Does not remove excess UV adhesive with razor blade, causes problem later
28	T	Wrong tool used to remove excess adhesive (cleaving tool instead of razor blade)
		Phase D (Steps 7-14): Initial and final polishing, splice assembly with matching gel, and testing product
29	Cg	Does not use alcohol to clean equipment or polishing block prior to beginning polish
30	D	Breaks ferrule by polishing with too much lateral force
31	T	Polishes with circular rather than figure-8 pattern
32	Cp	Does not clean ferrule with alcohol and cloth prior to inspecting polish
33	Sh(D)	Discovers shattered fiber or damaged ferrule face
34	P	Repolishing, removing excess adhesive, or difficulty deciding when polishing is completed and product is finished
35	T	Struggles with spring clip tool or lets clip snap out of tool
36	T	Insufficient or unequal portions of index matching gel
37	T	Does not fully close gap between gel and ferrules and unsure about alignment tabs
38	D	Breaks ferrule while twisting ferrules to obtain better OLTS reading
		All Phases (Steps 1-14 for Phases A, B, C, and D):
39	Sg	Not wearing safety glasses or wearing wrong safety glasses at some point during all phases

Note: Error types in parenthesis indicate a secondary classification that was not used, e.g., Cg(T) and Sh(D). Individual types of errors are only approximately in linear order within the sequential phases and are derived from the observer checklist given in Appendix B.

Table G-4
ST Connector Errors: Means, Standard Deviations, and Percents

Measure and Group	Traditional	Local	Remote	All Groups	Percent
Linear Phases:					
Phase A	2.44 (2.04)	1.12 (1.20)	1.06 (1.34)	1.58 (1.69)	36.4
Phase B	0.83 (0.99)	0.75 (0.77)	0.62 (1.02)	0.74 (0.92)	17.1
Phase C	0.78 (0.81)	0.94 (0.93)	0.62 (0.72)	0.78 (0.82)	17.9
Phase D	1.33 (2.17)	1.06 (1.12)	1.31 (1.74)	1.24 (1.72)	28.6
Sum Phases	5.39 (3.33)	3.88 (2.09)	3.62 (3.30)	4.34 (3.03)	100
Error Groups:					
Critical to Work Product	1.17 (0.99)	1.00 (1.32)	1.12 (0.96)	1.10 (1.07)	23.7
Fiber Care/Safety	1.17 (1.72)	1.12 (1.09)	0.56 (1.50)	0.96 (1.47)	20.7
Technique/Cleaning	2.61 (1.79)	1.38 (1.26)	1.56 (2.22)	1.88 (1.85)	40.5
Polishing	0.72 (1.45)	0.69 (0.95)	0.69 (1.01)	0.70 (1.15)	15.1
Sum Error Groups	5.67 (3.61)	4.19 (1.94)	3.94 (3.87)	4.64 (3.30)	100
Error Types:					
B-Breaks fiber	0.89 (0.83)	0.44 (0.73)	0.62 (0.62)	0.66 (0.75)	14.2
D-Connector Damage	0.00 (0.00)	0.12 (0.34)	0.06 (0.25)	0.06 (0.24)	1.3
Sh-Shatter/ferrule	0.11 (0.32)	0.31 (0.60)	0.31 (0.48)	0.24 (0.48)	5.2
Tc-Technique-critical	0.11 (0.32)	0.06 (0.25)	0.06 (0.25)	0.08 (0.27)	1.7
Lc-Length Prep-critical	0.06 (0.24)	0.06 (0.25)	0.06 (0.25)	0.06 (0.24)	1.3
Fc-Fiber Care	0.67 (0.97)	0.62 (0.96)	0.25 (0.58)	0.52 (0.86)	11.2
Sa-Safety	0.22 (0.73)	0.19 (0.40)	0.00 (0.00)	0.14 (0.50)	3.0
Sg-Safety Glasses	0.28 (0.75)	0.31 (0.60)	0.31 (1.01)	0.30 (0.79)	6.5
T-Technique	1.28 (1.36)	1.06 (1.12)	0.94 (1.06)	1.10 (1.18)	23.7
L-Length	0.39 (0.70)	0.19 (0.40)	0.31 (0.70)	0.30 (0.61)	6.5
Cg-Cleaning-General	0.94 (0.94)	0.12 (0.34)	0.31 (1.25)	0.48 (0.97)	10.3
Cp-Polish Cleaning	0.61 (1.24)	0.44 (0.73)	0.38 (0.81)	0.48 (0.95)	10.3
P-Polishing	0.11 (0.32)	0.25 (0.45)	0.31 (0.60)	0.22 (0.46)	4.7
Sum Types	5.67 (3.61)	4.19 (1.94)	3.94 (3.87)	4.64 (3.30)	100
Number of Students	18	16	16	50	

Means are followed by standard deviations within parentheses. Phases do not include safety glasses. Percent of errors within phases, groups, or types are for all 50 students.

Table G-5
Rotary Connector Errors: Means, Standard Deviations, and Percents

Measure and Group	Traditional	Local	Remote	All Groups	Percent
Linear Phases:					
Phase A	1.11 (1.32)	1.19 (1.38)	1.12 (1.41)	1.14 (1.34)	34.8
Phase B	0.50 (0.62)	0.44 (0.63)	0.56 (0.73)	0.50 (0.65)	15.2
Phase C	0.61 (0.92)	0.69 (0.70)	0.56 (0.63)	0.62 (0.75)	18.9
Phase D	1.06 (1.06)	0.88 (0.89)	1.12 (1.20)	1.02 (1.04)	31.1
Sum Phases	3.28 (2.65)	3.19 (2.54)	3.38 (2.60)	3.28 (2.55)	100
Error Groups:					
Critical to Work Product	1.17 (1.25)	0.69 (1.08)	1.06 (1.06)	0.98 (1.13)	26.3
Fiber Care/Safety	1.06 (1.59)	1.19 (1.56)	1.00 (0.89)	1.08 (1.37)	29.0
Technique/Cleaning	1.17 (1.38)	1.38 (1.36)	1.19 (1.17)	1.24 (1.29)	33.3
Polishing	0.39 (0.78)	0.38 (0.50)	0.50 (1.03)	0.42 (0.78)	11.3
Sum Error Groups	3.78 (2.98)	3.62 (2.73)	3.75 (2.54)	3.72 (2.71)	100
Error Types:					
B-Breaks fiber	0.28 (0.57)	0.25 (0.58)	0.50 (0.89)	0.34 (0.69)	9.1
D-Connector Damage	0.22 (0.43)	0.12 (0.34)	0.06 (0.25)	0.14 (0.35)	3.8
Sh-Shatter/ferrule	0.28 (0.46)	0.06 (0.25)	0.12 (0.34)	0.16 (0.37)	4.3
Tc-Technique-critical	0.11 (0.32)	0.12 (0.34)	0.19 (0.40)	0.14 (0.35)	3.8
Lc-Length Prep-critical	0.28 (0.46)	0.12 (0.34)	0.19 (0.40)	0.20 (0.40)	5.4
Fc-Fiber Care	0.39 (0.85)	0.50 (1.21)	0.50 (0.89)	0.46 (0.97)	12.4
Sa-Safety	0.17 (0.38)	0.25 (0.45)	0.12 (0.34)	0.18 (0.39)	4.8
Sg-Safety Glasses	0.50 (0.86)	0.44 (0.81)	0.38 (0.62)	0.44 (0.76)	11.8
T-Technique	0.61 (0.78)	0.88 (1.09)	0.69 (0.95)	0.72 (0.93)	19.3
L-Length	0.22 (0.43)	0.25 (0.45)	0.12 (0.34)	0.20 (0.40)	5.4
Cg-Cleaning-General	0.33 (0.59)	0.25 (0.58)	0.38 (0.62)	0.32 (0.59)	8.6
Cp-Polish Cleaning	0.17 (0.38)	0.06 (0.25)	0.19 (0.75)	0.14 (0.50)	3.8
P-Polishing	0.22 (0.43)	0.31 (0.48)	0.31 (0.48)	0.28 (0.45)	7.5
Sum Types	3.78 (2.98)	3.62 (2.73)	3.75 (2.54)	3.72 (2.71)	100
Number of Students	18	16	16	50	

Means are followed by standard deviations within parentheses. Phases do not include safety glasses. Percent of errors within phases, groups, or types are for all 50 students.

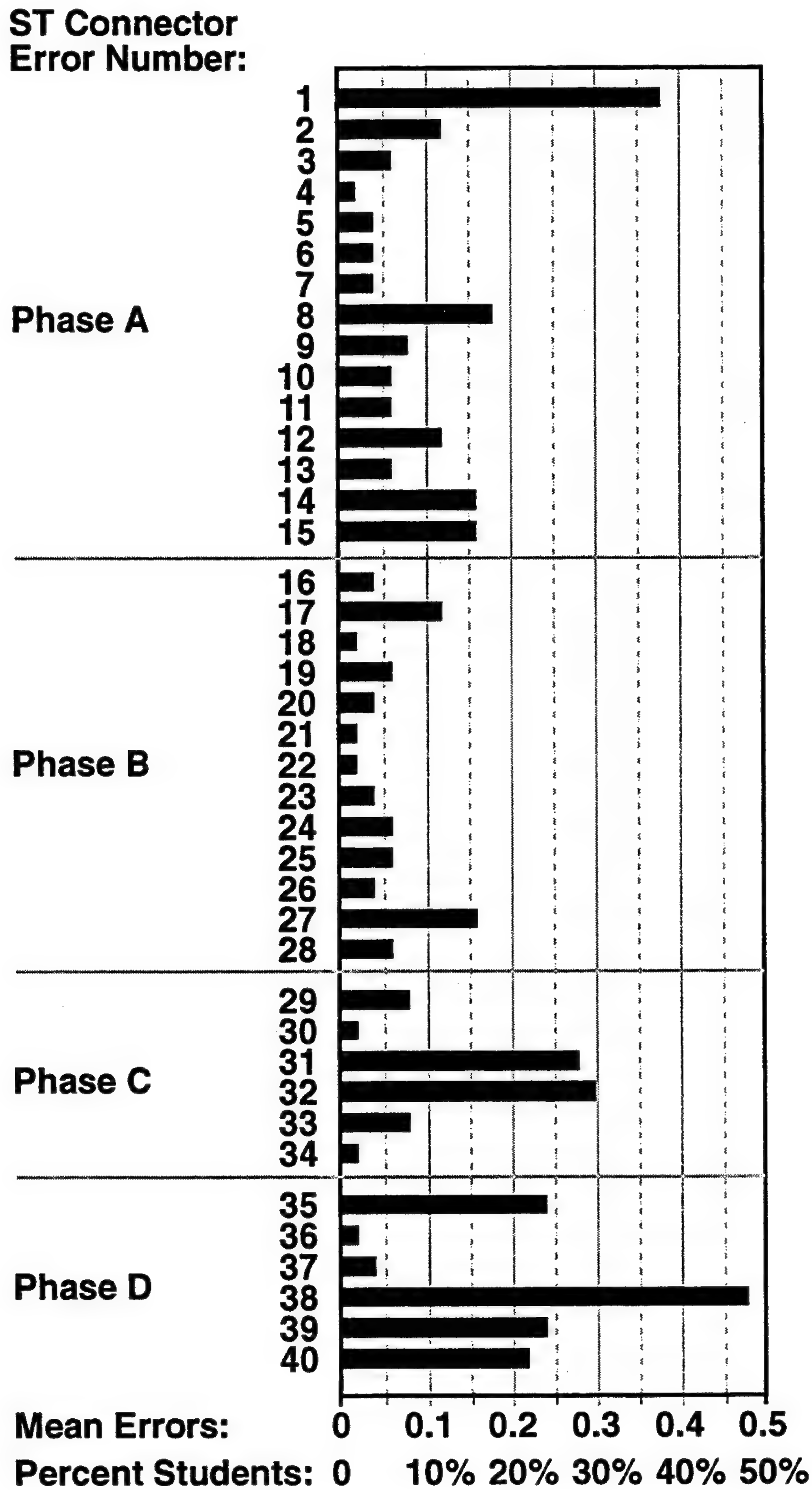

Figure G-1. ST connector errors listed by individual error numbers from Table G-2.

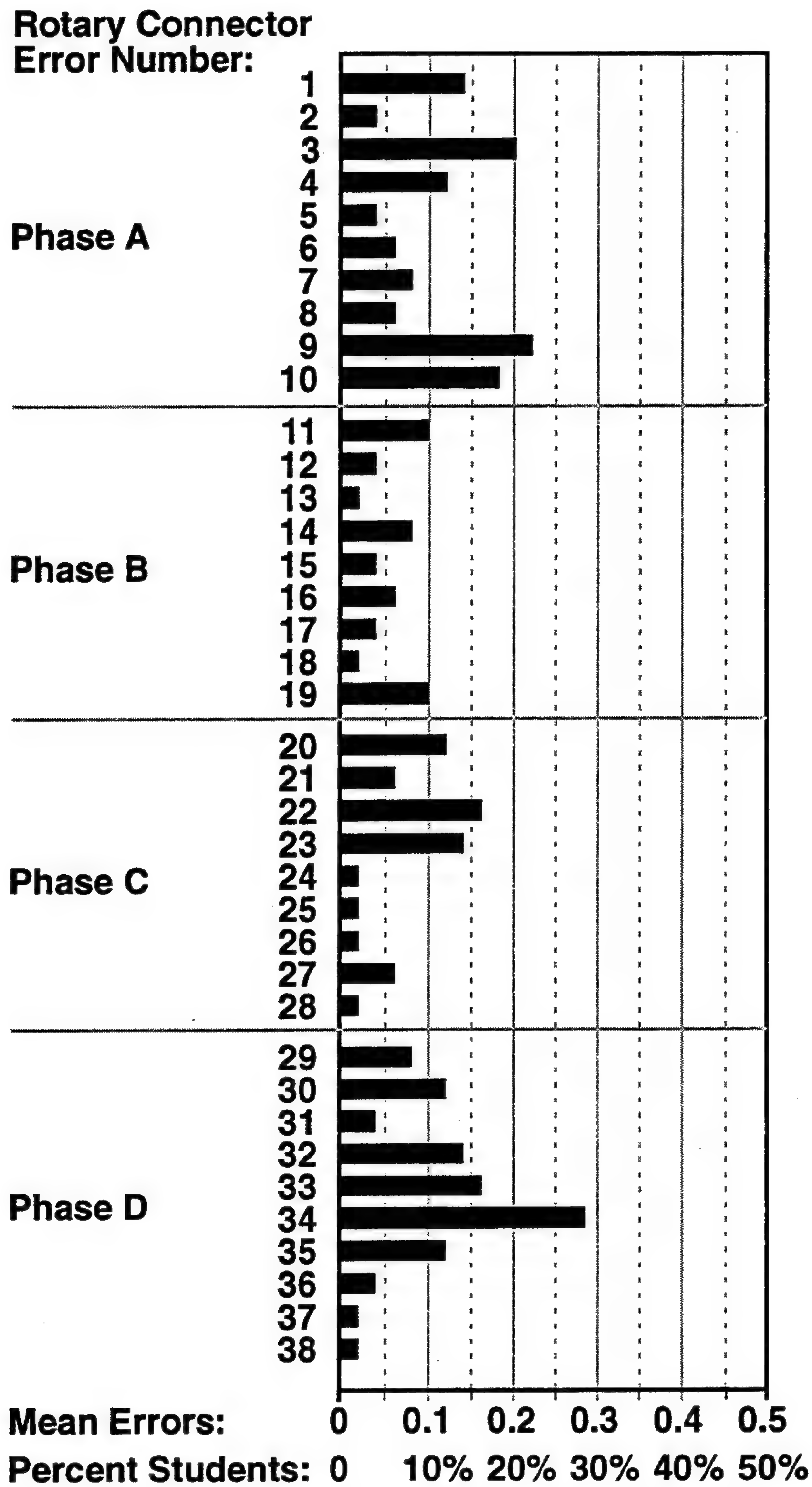

Figure G-2. Rotary Splice connector errors listed by individual error numbers from Table G-3.

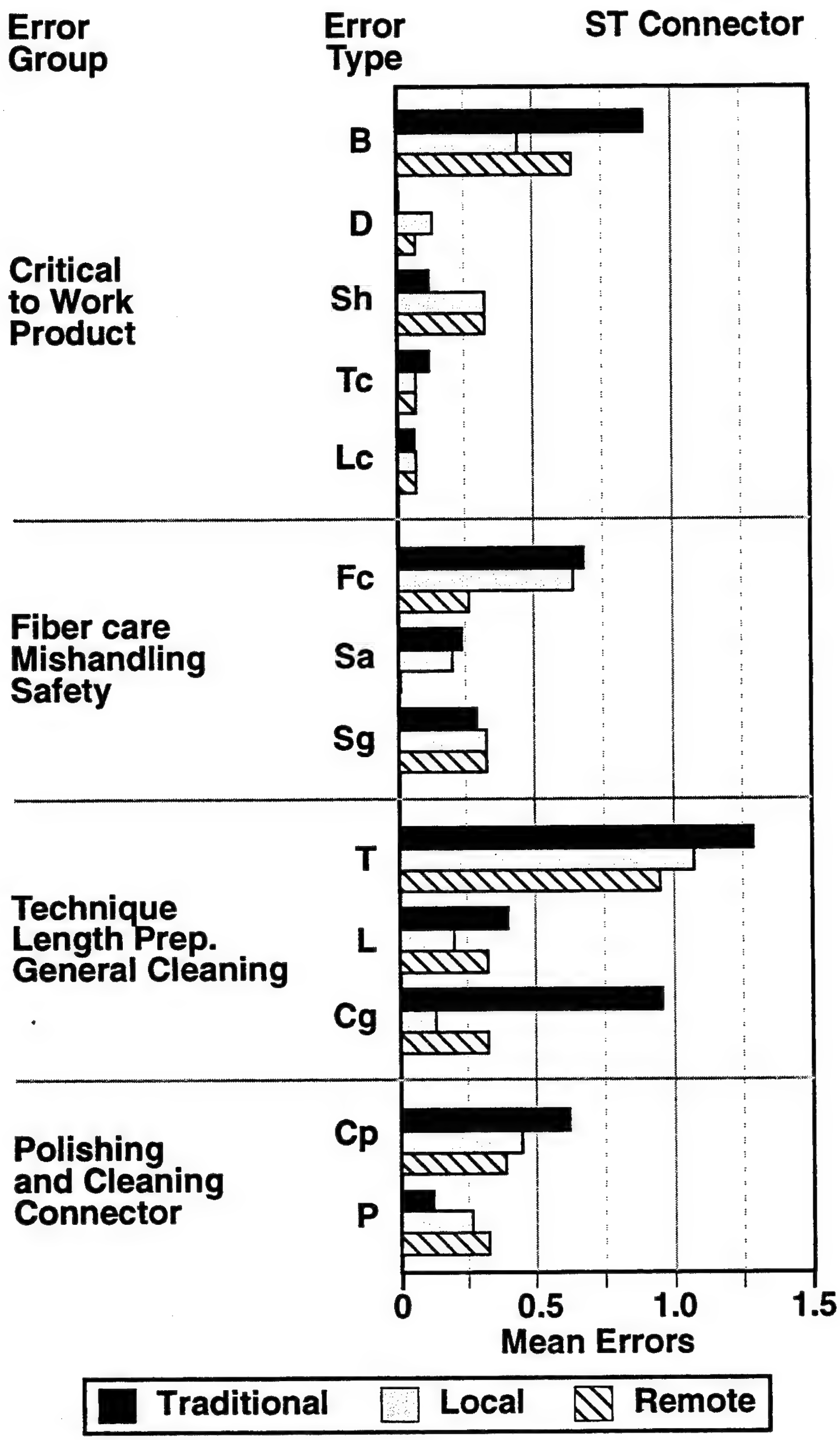

Figure G-3. **ST connector errors listed by error type abbreviations given in Table G-1.**

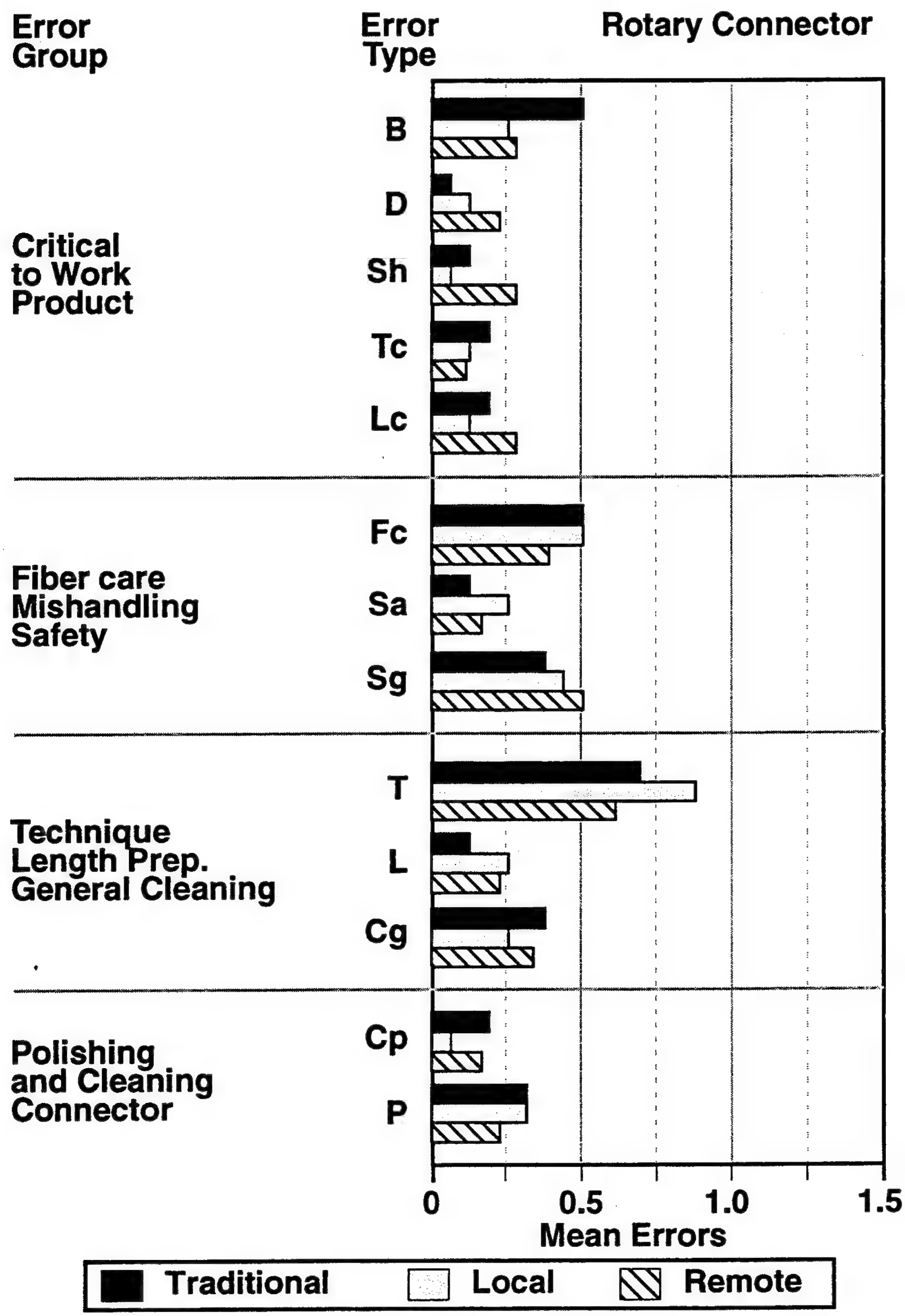

Figure G-4. Rotary Splice connector errors listed by error type abbreviations given in Table G-1.

Appendix H

Student Questionnaire Results

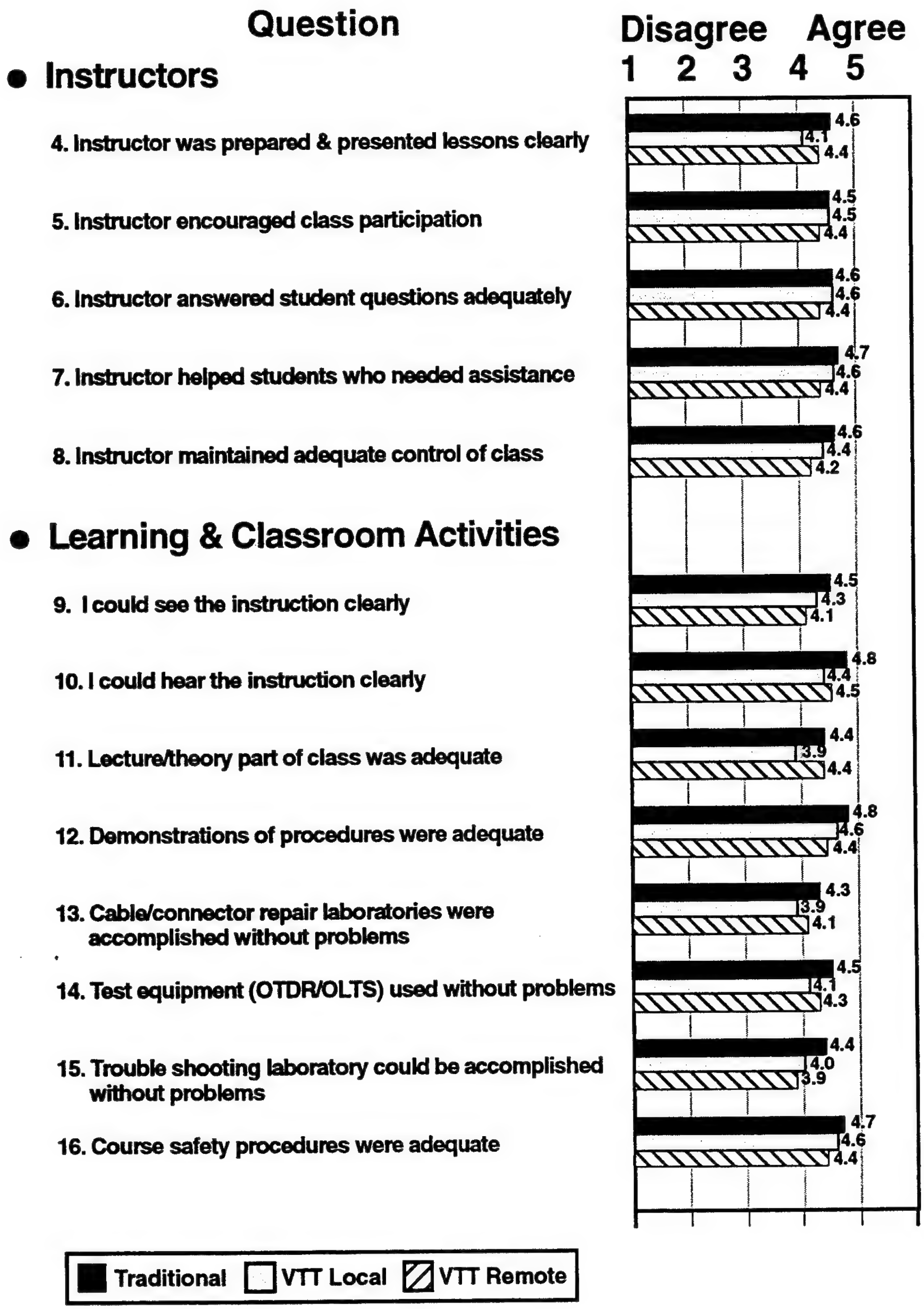

Figure H-1. Student responses on questionnaire rating items 4-16.

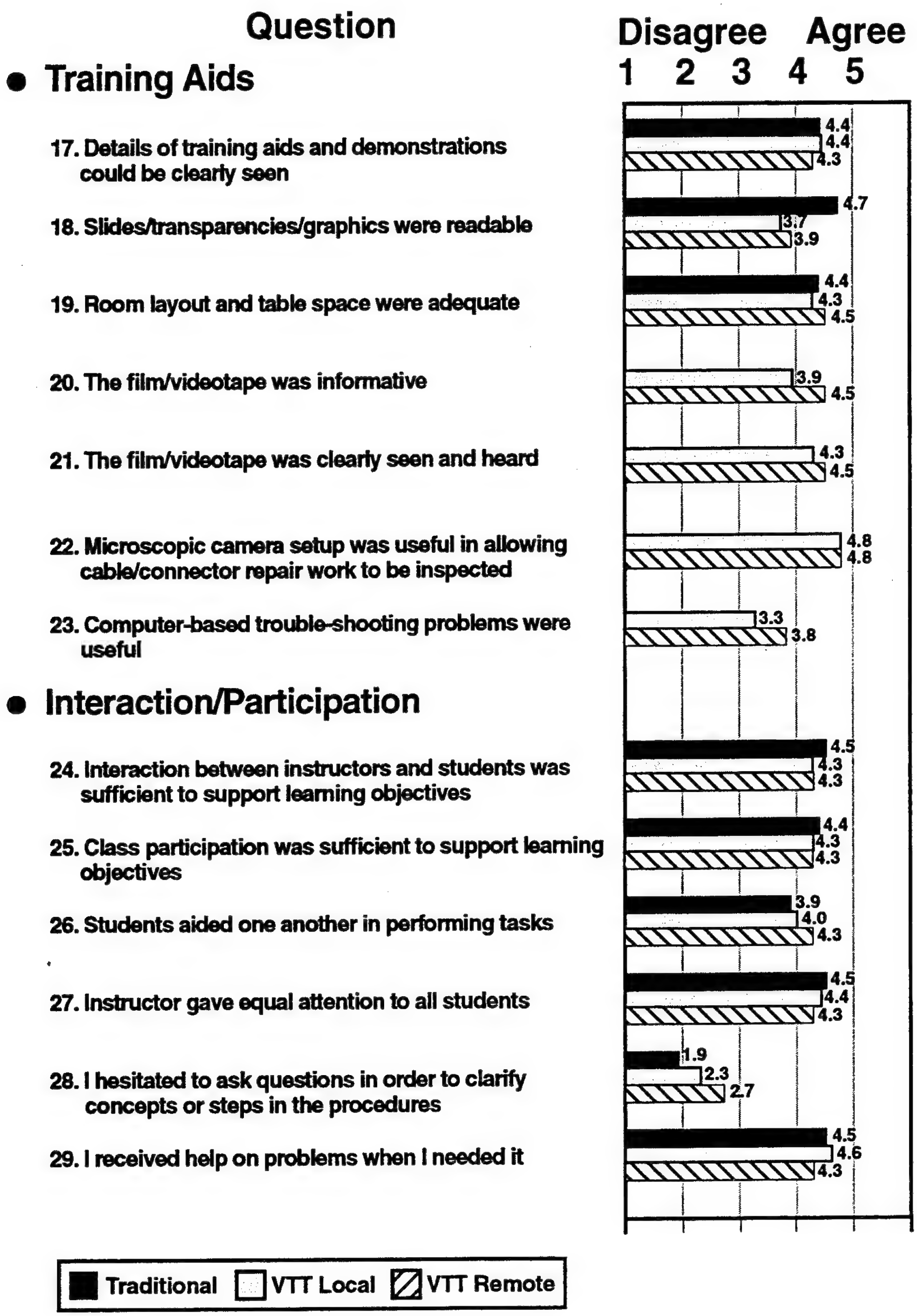

Figure H-2. Student responses on questionnaire rating items 17-29.

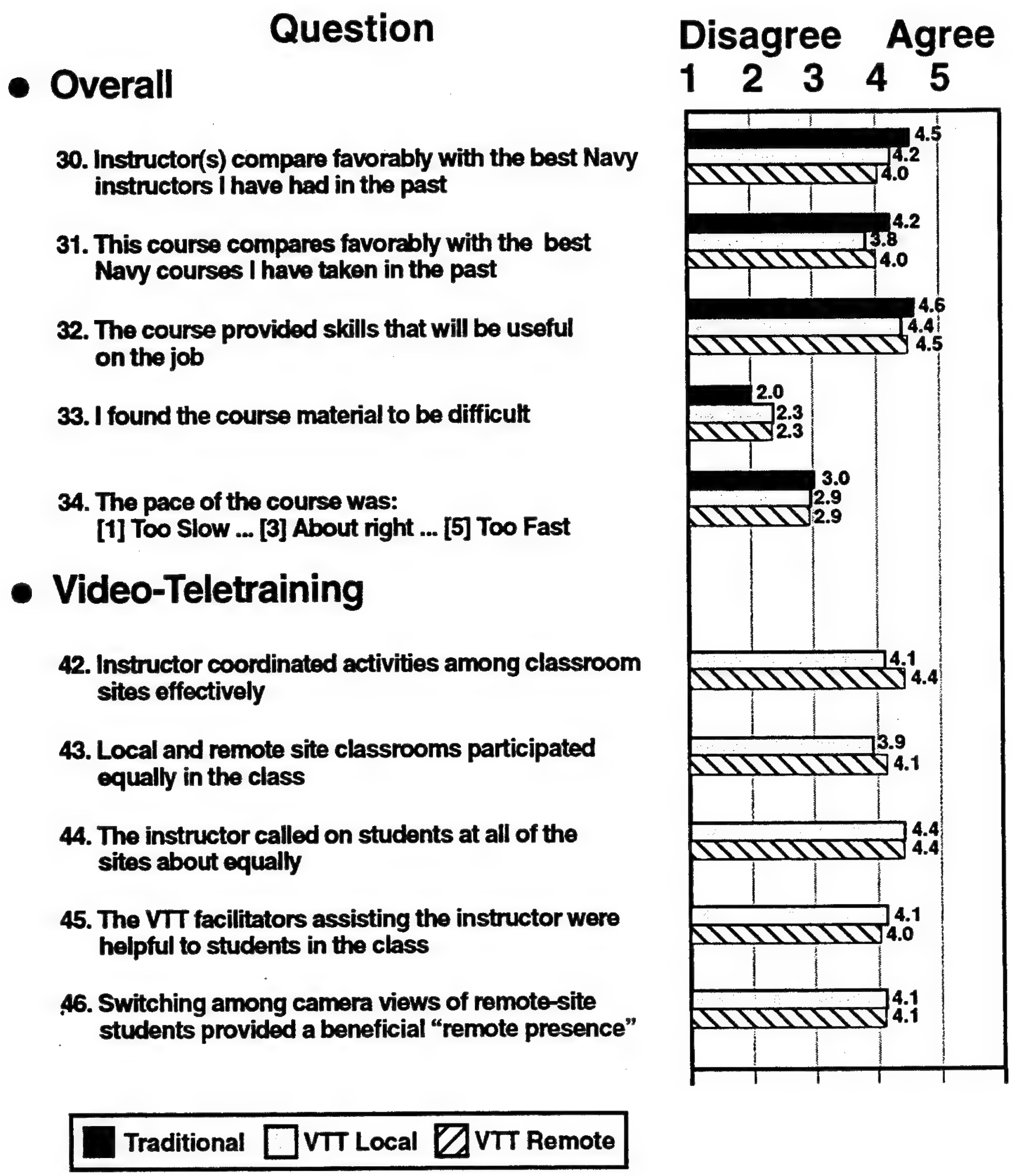

Figure H-3. Student responses on questionnaire rating items 30-34 and 42-46.

Table H-1

Student Background Statistics

Rating Item and Number of Students	Treatment Group: Traditional	VTT Local	VTT Remote
1. Before this course, I had basic knowledge of fiber optic concepts and facts	2.55	3.13	2.25
2. Before this course, I was proficient at performing the fiber optic cable repair tasks	1.55	1.94	1.81
3. Before this course, I was proficient at performing the fiber optic trouble shooting tasks	1.50	1.88	1.75
Average Military Rank	5.1	5.2	4.9
Number of Students in Electronics Technician (ET) Rating	13	13	13
Number of Students in Interior Communications (IC) Rating	3	2	1
Number of Students in Data System Technician (DS) Rating	0	1	2
Number of Students in Other Ratings	2	0	0
Total Number of Students	18	16	16

Note: Questionnaire rating items 1 to 3 were rated on a five point scale with a value of 1 for "strongly disagree" and 5 for "strongly agree".

Table H-2

Statistical Comparisons for Student Questionnaire Rating Items.

Question	ANOVA T-L-R or L-R DF	F	Mean Differences and Tukey HSD Comparisons T-L	T-R	L-R
BACKGROUND					
1. Before this course, I had basic knowledge of fiber optic concepts and facts	2,47	1.79	-0.57	0.31	0.88
2. Before this course, I was proficient at performing the fiber optic cable repair tasks	2,47	0.57	-0.38	-0.26	0.13
3. Before this course, I was proficient at performing the fiber optic trouble shooting tasks	2,47	0.55	-0.38	-0.25	0.13
INSTRUCTORS					
4. Instructor was prepared & presented lessons clearly	2,47	2.32	0.43	0.18	-0.25
5. Instructor encouraged class participation	2,47	0.28	0.00	0.13	0.12
6. Instructor answered student questions adequately	2,47	0.71	-0.01	0.18	0.19
7. Instructor helped students who needed assistance	2,47	2.12	0.16	0.35	0.19
8. Instructor maintained adequate control of class	2,47	1.95	0.24	0.42	0.19
LEARNING & CLASSROOM ACTIVITIES					
9. I could see the instruction clearly	2,47	1.16	0.25	0.38	0.13
10. I could hear the instruction clearly	2,47	2.41	0.34	0.28	-0.06
11. Lecture/theory part of class was adequate	2,47	3.38*	0.51	-0.05	-0.56
12. Demonstrations of procedures were adequate	2,47	2.02	0.27	0.40	0.13
13. Cable/connector repair laboratories were accomplished without problems	2,47	0.78	0.46	0.27	-0.19
14. Test equipment (OTDR/OLTS) used without problems	2,47	1.58	0.38	0.19	-0.19
15. Trouble shooting laboratory could be accomplished without problems	2,47	1.16	0.44	0.51	0.06
16. Course safety procedures were adequate	2,47	1.68	0.04	0.29	0.25

Mean differences are: T-L = Traditional-Local; T-R = Traditional-Remote; L-R = Local-Remote
*p<.05 **p<.01 ; Scale for all items except item #34 is:
[1] Strongly Disagree [2] Disagree [3] Neither Agree/Disagree [4] Agree [5] Strongly Agree

Table H-2 Continued

Question	ANOVA T-L-R or L-R		Mean Differences and Tukey HSD Comparisons		
	DF	F	T-L	T-R	L-R
TRAINING AIDS					
17. Details of training aids and demonstrations could be clearly seen	2,47	0.36	0.07	0.19	0.13
18. Slides/transparencies/graphics were readable	2,47	7.38**	0.98**	0.73*	-0.25
19. Room layout and table space were adequate	2,46	0.29	0.11	-0.06	-0.17
20. The film/videotape was informative	1,29	5.43*	----	----	-0.60*
21. The film/videotape was clearly seen and heard	1,29	1.53	----	----	-0.22
22. Microscopic camera setup was useful in allowing cable/connector repair work to be inspected	1,30	0.17	----	----	0.06
23. Computer-based trouble-shooting problems were useful	1,30	2.51	----	----	-0.50
INTERACTION/PARTICIPATION					
24. Interaction between instructors and students was sufficient to support learning objectives	2,47	0.84	0.19	0.19	0.00
25. Class participation was sufficient to support learning objectives	2,47	0.47	0.13	0.19	0.06
26. Students aided one another in performing tasks	2,47	0.94	-0.06	-0.31	-0.25
27. Instructor gave equal attention to all students	2,47	0.82	0.13	0.25	0.12
28. I hesitated to ask questions in order to clarify concepts or steps in the procedures	2,47	1.72	-0.37	-0.74	-0.38
29. I received help on problems when I needed it	2,47	0.67	-0.13	0.19	0.31
OVERALL					
30. Instructor(s) compare favorably with the best Navy instructors I have had in the past	2,47	1.66	0.31	0.50	0.19
31. This course compares favorably with the best Navy courses I have taken in the past	2,47	0.88	0.42	0.17	-0.25
32. The course provided skills that will be useful on the job	2,47	0.17	0.12	0.06	-0.06
33. I found the course material to be difficult	2,47	0.68	-0.31	-0.31	0.00
34. The pace of the course was: [1] Too-Slow [2] Somewhat-Slow [3] About-right [4] Somewhat-Fast [5] Too-Fast	2,47	0.66	0.13	0.06	-0.06

Mean differences are: T-L = Traditional-Local; T-R = Traditional-Remote; L-R = Local-Remote
*p<.05 **p<.01 ; Traditional students were not administered items 20-23.
Scale for all items except item #34 is:
[1] Strongly Disagree [2] Disagree [3] Neither Agree/Disagree [4] Agree [5] Strongly Agree

Table H-2 Continued

Question	ANOVA T-L-R or L-R DF	F	Mean Differences and Tukey HSD Comparisons T-L	T-R	L-R
ADEQUACY OF PORTIONS OF COURSE					
35. Lectures	2,47	1.01	0.24	-0.08	-0.31
36. Instructor demonstrations of cable repair	2,47	0.20	0.14	-0.05	-0.19
37. Videotaped demonstrations of cable repair	1,30	3.11	----	----	-0.56
38. My own cable repair work with ST, Rotary Splice and Veam/Hughes connectors	2,47	2.74	0.62	0.06	-0.56
39. Instructor demonstrations of OLTS/OTDR and trouble shooting of cable system	2,47	0.97	0.25	-0.19	-0.44
40. My work with OLTS/OTDR and trouble shooting the cable system	2,47	1.52	0.55	0.17	-0.38
41. Ability of students to get help	2,47	0.56	0.14	0.33	0.19
VIDEO-TELETRAINING					
42. Instructor coordinated activities among classroom sites effectively	1,30	2.19	----	----	-0.31
43. Local and remote site classrooms participated equally in the class	1,30	0.51	----	----	-0.25
44. The instructor called on students at all of the sites about equally	1,30	0.00	----	----	0.00
45. The VTT facilitators assisting the instructor were helpful to students in the class	1,30	0.04	----	----	0.06
46. Switching among camera views of remote-site students provided a beneficial "remote presence"	1,30	0.00	----	----	0.00

Mean differences are: T-L = Traditional-Local; T-R = Traditional-Remote; L-R = Local-Remote
*p<.05 **p<.01 ; Traditional students were not administered items 37 and 42-46.
Scale for all items except item #34 is:
[1] Strongly Disagree [2] Disagree [3] Neither Agree/Disagree [4] Agree [5] Strongly Agree

Table H-3

Percent Responses on Multiple Choice Questionnaire Items 47 to 50

	Treatment Group		
Question and Answer Category	Traditional	VTT Local	VTT Remote
Number of students per group	18	16	16
47. Who most frequently provided assistance to you:			
Instructor	-----	93.75	81.25
Other students	-----	0.00	12.50
Facilitator	-----	0.00	0.00
Other (combination of above)	-----	6.25	6.25
Total Percent	100.00	100.00	100.00
48. Which method of instruction would you prefer for this course:			
Video Tele-Training (VTT)	0.00	6.25	25.00
Either method	29.41	56.25	50.00
Traditional method (non-VTT)	70.59	37.50	25.00
Total Percent	100.00	100.00	100.00
Number with no answer	1	0	0
49. How did the VTT method of instruction affect your opportunities to interact with the instructor?			
More opportunities	-----	12.50	12.50
No effect on opportunities	-----	87.50	75.00
Fewer opportunities	-----	0.00	12.50
Total Percent	100.00	100.00	100.00
50. If you had a choice, would you take another VTT course?			
Yes	-----	100.00	100.00
No	-----	0.00	0.00
Total Percent	100.00	100.00	100.00
Number with no answer	-----	1	0

Note: Only item 48 was administered to all three treatment groups.
Percents exclude students who did not answer.

Table H-4

Percentage of Treatment Group Responses to Open-Ended Question Number 50 "If you had a choice, would you take another VTT course ?"

	Treatment Group		
Group and Comment Category	VTT Local	VTT Remote	Combined Groups
Positive Comment	62.50	75.00	68.75
Positive and Negative Comment	31.25	18.75	25.00
No Comment	6.25	6.25	6.25
Total Percent	100	100	100
Total Students	16	16	32

Note: Positive comments indicated acceptance of VTT or no perceived difference between VTT and traditional instruction. Positive and negative comments indicated acceptance of VTT combined with a qualification, such as hands-on laboratories would be difficult to do with VTT, need to improve some visuals, or a preference for live instruction. In the first part of this question, 31 students choose "yes", indicating they would take another VTT course (one local student did not answer).

Table H-5

Percentage of Students in Each Treatment Group That Offered Comments to Open-Ended Questions (Items 51, 52, and 53)

	Treatment Group			
Group and Question	Traditional	Local	Remote	All Groups
51. Liked most about course	100.0	100.0	100.0	100.0
52. Liked least about course	55.5	75.0	87.5	72.0
53. Suggestions for improvement	83.3	87.5	93.7	88.0
Total Number of Students	18	16	16	50

Note: percentages of total students that gave one or more comments to a question

Table H-6

Percentage of Treatment Group Responses to Open-Ended Question "What did you like the most about this course?"

	Treatment Group			
Group and Comment Category	Traditional	Local	Remote	All Groups
a. Final Test	0	0	0	0
b. Student Guide	0	0	0	0
c. Demonstrations or Videotapes	0	8.0	0	2.7
d. Connector Laboratories	35.5	28.0	16.7	28.4
e. Trouble-shooting Laboratory or CBI	35.5	28.0	16.7	28.4
f. Videoteletraining (VTT)	0	16.0	38.9	14.9
g. Learning New Technology	29.0	20.0	27.7	25.6
h. Presentation	0	0	0	0
i. Laboratory Materials	0	0	0	0
j. Facilities	0	0	0	0
k. Laboratory or Course Length	0	0	0	0
No Comment	0	0	0	0
Total Percent	100.0	100.0	100.0	100.0
Number of 1st Comments	18	16	16	50
Number of 2nd Comments	11	4	2	17
Number of 3rd Comments	2	3	0	5
Number of 4th Comments	0	2	0	2
Total Comments	31	25	18	74
Number No Comment	0	0	0	0
Total Comments and No Comment	31	25	18	74
Number of Students	18	16	16	50

Note: Divisor for percents was total of comments and no comment

a. Final Test (none).

b. Student Guide (none).

c. Demonstrations or Videotapes (helpful, appropriate, innovative).

d. Connector Laboratories (job related, helpful practice, challenging, appropriate).

e. Trouble-shooting Laboratory or Computer Based Instruction (CBI) (job related, helpful practice, challenging, appropriate).

f. Videoteletraining (liked VTT instruction, technology, interaction, or using VTT system).

g. Learning New Technology (benefit of learning new fiber optic technology, new kinds of test equipment, civilian compatible).

h. Presentation (none).

i. Laboratory Materials (none).

j. Facilities (none).

k. Laboratory or Course Length (none).

Table H-7

Percentage of Treatment Group Responses to Open-Ended Question "What did you like the least about this course?"

Group and Comment Category	Treatment Group: Traditional	Local	Remote	All Groups
a. Final Test	5.6	17.4	23.5	15.5
b. Student Guide	11.1	17.4	11.8	13.8
c. Demonstrations or Videotapes	0	0	5.9	1.7
d. Connector Laboratories	0	0	5.9	1.7
e. Trouble-shooting Laboratory or CBI	0	0	0	0
f. Videoteletraining (VTT)	0	4.3	11.8	5.2
g. Learning New Technology	0	0	0	0
h. Presentation	11.1	8.7	17.5	12.1
i. Laboratory Materials	5.6	26.1	5.9	13.8
j. Facilities	16.6	4.3	0	6.9
k. Laboratory or Course Length	5.6	4.3	5.9	5.2
No Comment	44.4	17.4	11.8	24.1
Total Percent	100.0	100.0	100.0	100.0
Number of 1st Comments	10	12	14	36
Number of 2nd Comments	0	4	1	5
Number of 3rd Comments	0	3	0	3
Total Comments	10	19	15	44
Number No Comment	8	4	2	14
Total Comments and No Comment	18	23	17	58
Number of Students	18	16	16	50

Note: Divisor for percents was total of comments and no comment
a. Final Test (disputes over some test items or content in some items, some equipment questions not covered in course).
b. Student Guide (contains different test equipment than used in course).
c. Demonstrations or Videotapes (difficulty seeing).
d. Connector Laboratories (not job related, inappropriate, too difficult).
e. Trouble-shooting Laboratory or Computer Based Instruction (CBI) (none).
f. Videoteletraining (not enough interaction, help from instructor/facilitator).
g. Learning New Technology (none).
h. Presentation (difficulty in seeing some slides/visuals, some lecture points not clear).
i. Laboratory Materials (lack connector supplies, especially Hughes connector).
j. Facilities (classroom temperature, building).
k. Laboratory or Course Length (too long, too short).

Table H-8

Percentage of Treatment Group Responses to Open-Ended Question "Discuss any suggestions you have for improving the course"

Group and Comment Category	Traditional	Local	Remote	All Groups
	Treatment Group			
a. Final Test	0	20.8	9.1	8.5
b. Student Guide	0	12.5	0	3.7
c. Demonstrations or Videotapes	11.1	0	9.1	7.3
d. Connector Laboratories	8.3	4.2	0	4.9
e. Trouble-shooting Laboratory or CBI	19.5	4.2	4.5	11.0
f. Videoteletraining (VTT)	0	4.2	18.2	6.1
g. Learning New Technology	0	0	0	0
h. Presentation	11.1	4.2	18.2	11.0
i. Laboratory Materials	16.7	33.3	9.1	19.5
j. Facilities	0	0	4.5	1.2
k. Laboratory or Course Length	25.0	8.3	22.7	19.5
No Comment	8.3	8.3	4.5	7.3
Total Percent	100.0	100.0	100.0	100.0
Number of 1st Comments	15	12	15	42
Number of 2nd Comments	12	7	6	25
Number of 3rd Comments	4	2	0	6
Number of 4th Comments	2	1	0	3
Total Comments	33	22	21	76
Number No Comment	3	2	1	6
Total Comments and No Comment	36	24	22	82
Number of Students	18	16	16	50

Note: Divisor for percents was total of comments and no comment
a. Final Test (fix discrepancy between test items and equipment used in course).
b. Student Guide (cover equipment used in course).
c. Demonstrations or Videotapes (make easier to understand and see).
d. Connector Laboratories (more practice making connectors).
e. Trouble-shooting Laboratory or Computer Based Instruction (CBI)
(have more troubleshooting variations and attempts).
f. Videoteletraining (more interaction).
g. Learning New Technology (none).
h. Presentation (increase quality of slides, interaction, appropriateness).
i. Laboratory Materials (need more connector laboratory supplies, e.g., Hughes connector).
j. Facilities (room temperature, different room).
k. Laboratory or Course Length (more laboratory time, greater variety of fiber systems).

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